VOLUME XXIV NUMBER 3

BOTANICAL GAZETTE

SEPTEMBER 1897

PHYLOGENY AND TAXONOMY OF THE ANGIOSPERMS.[1]

CHARLES E. BESSEY.

IT is unnecessary for me to state at the outset what is evident to every botanist, that it is as yet impossible to present a complete phylogeny of the angiosperms. Phytopalæontology is too young a science, and the materials with which it deals are yet far too scanty to have given us direct evidence as to the phylogeny of all families of plants. No one can trace with great certainty from the fossil remains of plants yet discovered the genealogy of any considerable portion of the vegetable kingdom. It will be many a year before the direct evidence we so much desire will leave no considerable gaps to be filled by skillful interpolation. However, after making all due allowance for the imperfection of the record, there are many facts as to past vegetation which are well established. Thus, we know that the earliest plants were simple, homogeneous-celled, aquatic organisms. We know that ferns and gymnosperms preceded angiosperms. We know that the angiosperms which first appeared were of lower types, and that the highest types known today were wanting until very late in geological time.

It is true, moreover, that we are not confined to the direct evidence furnished by the palæontological record. In the individual development of every plant (ontogenesis) there is a

[1] Address of the retiring President of the Botanical Society of America, delivered at Toronto, August 17, 1897.

recapitulation of its ancestral development (phylogenesis). A critical study of the development of the individual must throw light upon the past history of the species. When we know every step in the formation of each plant we shall be able to trace the phylogeny of every species. Here again we have to face the fact that our knowledge is still quite fragmentary, and that on this account the results are not as definite as we could wish. And yet, when we bring together what we know of the ontogeny of plants here and there in the higher groups, we are able to make out with much certainty not a little as to their phylogeny. To the details regarding these results I shall advert somewhat later.

There is still another line of inquiry open to us, namely, the morphological, in which account is taken of the varying development of homologous tissues, members, and organs. Rightly interpreted, the results of morphological studies are of very high importance in determining genetic relationships. When differences in homologous parts are regarded as but the expression of variation from a common form, they become indices of relationship, and when these indices, obtained from all the tissues, members, and organs of a group of plants, are judiciously considered, they mark out lines of descent with great distinctness.

We have thus open to us three lines of investigation in the study of the phylogeny of plants, namely, (1) the historical, in which the materials are supplied by phytopalæontology, (2) the ontogenetic, in which the development of the individual supplies us with the necessary data, and (3) the morphological, in which the different development of homologous parts is our index of relationship. In this paper I purpose to bring these three lines of investigation to bear upon the problem of the phylogeny of the angiosperms.

GENERAL RESULTS FROM PHYTOPALÆONTOLOGY.

In the Devonian period plants underwent such modifications that we pretty clearly recognize the three types which constitute

the present classes of the pteridophytes,—the ferns, joint-rushes, and lycopods. There appears to be no doubt that heterospory was attained by some of the Devonian pteridophytes. The Lepidodendreæ were quite certainly heterosporous, and possibly the Psilophyteæ should be admitted also. Certain it is that the conifers of this period were heterosporous.

In the Carboniferous and Permian the species and genera of then existing types were multiplied, and the cycads, another heterosporous type, were added. This tendency to heterospory soon resulted in the appearance of plants referred by some authors to the monocotyledons. It is pretty certain at any rate that monocotyledons appeared late in the Palæozoic period or early in the Mesozoic. Of dicotyledons no fossils have been determined with certainty earlier than the Cretaceous, in which period they were evidently quite abundant.

If now we examine with some detail the fossil remains of the angiosperms we find that the earliest recognized were monocotyledons with superior ovaries (Palæospatha, Spirangium, Yuccites, from the Permocarboniferous and the early Mesozoic). Making due allowance for possible errors of determination we find that by the end of the Jurassic period the monocotyledons were probably represented by members of the groups (orders) Apocarpæ, Coronarieæ, Calycinæ, and Glumaceæ. To these we may add, in the Cretaceous, a few representatives of the Epigynæ. In the Tertiary the plants determined are referred to the Apocarpæ, Coronarieæ, Nudifloræ, Calycinæ, Glumaceæ, Hydrales, and Epigynæ. It is interesting to note that the monocotyledonous plants of the Tertiary have been referred mainly to the hypogynous orders, and that none have been identified as representing the Microspermæ. Apparently the evolution of the monocotyledons began with hypogynous species and proceeded toward those in which epigyny is most marked. Orchids are doubtless of very late evolution, so late in fact that none have been preserved as fossils.

The foregoing facts are presented below in tabular form, the per cent. of representation of each group being given for each

period. The data for this table are derived from Schimper,[2] Lesquereux,[3] and Durand.[4]

	Triassic	Jurassic	Cretaceous		Eocene	Miocene	Present
			Lesquereux	Schimper			
Apocarpæ		30.8	12.5	26.6	29.3	16.1	1.0
Coronarieæ	100.0	38.4	25.0	6.6	4.3	19.4	14.0
Nudifloræ		7.7	12.5	33.3	14.1	7.0	5.5
Calycinæ		7.7	12.5	26.6	22.8	21.8	6.7
Glumaceæ		15.3	12.5	....	25.0	28.3	31.6
Hydrales			0.0	0.0	1.1	1.6	.05
Epigynæ			25.0	6.6	3.3	5.6	14.0
Microspermæ				0.0	0.0	0.0	25.7

The history of the dicotyledons, as far as yet made out, is relatively simple. In the Cretaceous we find that from 90 to 95 per cent. of the known species may be referred to the two primitive groups (orders) Thalamifloræ and Calycifloræ. Taking Schimper's results, we find that nearly 60 per cent. are referable to the Thalamifloræ, representing nearly equally the groups (sub-orders) Ranales, Caryophyllales, and Malvales. The less important groups, Parietales, Polygalales, Geraniales, and Guttiferales, have not yet appeared; at least no representatives have been certainly recognized.

The Calycifloræ are represented by species of Rosales, Myrtales, Celastrales, Sapindales, and Umbellales. Here the numbers are quite unequal, ranging from about 10 per cent. for Myrtales and Umbellales, to 13 per cent. for Rosales, 26 per cent. for Celastrales, and 40 per cent. for Sapindales. The Heteromeræ and Bicarpellatæ were scarcely represented, Schimper recording but a single species each of Ericales, Ebenales, and Gentianales. If we make use of the data brought together by Lesquereux,[5] we find little change in the general results. There is here a slight preponderance of Calycifloræ

[2] Traité de Palæontologie Végétale. 1869–1874.
[3] The Flora of the Dakota Group. 1891.
[4] Index Generum Phanerogamarum. 1888.
[5] The Flora of the Dakota Group. 1891.

over the Thalamifloræ, 52 per cent. of the former to 48 per cent. of the latter. We note, moreover, that the Ranales include nearly 50 per cent. of the Thalamifloræ, the Caryophyllales 16 per cent., and the Malvales 34 per cent. In the Calycifloræ the Myrtales have but 4 per cent., the Umbellales 12 per cent., the Rosales 24 per cent., and the Celastrales and Sapindales about 30 per cent. each. The Heteromeræ are represented by a few species of Primulales, Ericales, and Ebenales, and there are no Bicarpellatæ whatever. Of the Inferæ there are eight species of Rubiales. It will be instructive to place these results side by side in tabular form.

	Per cent. of species Schimper			Per cent. of species Lesquereux		
CHORIPETALÆ AND APETALÆ	96			92		
Thalamifloræ		60			48	
Ranales			34			50
Parietales			0			0
Polygalales			0			0
Caryophyllales			32			16
Geraniales			0			0
Guttiferales			0			0
Malvales			34			34
Calycifloræ		40			52	
Rosales			13			24
Myrtales			10			4
Passiflorales			0			0
Cactales			0			0
Celastrales			26			30
Sapindales			40			30
Umbellales			10			12
GAMOPETALÆ	4			8		
Heteromeræ		66			72	
Primulales			0			10
Ericales			50			45
Ebenales			50			45
Bicarpellatæ		33			0	
Gentianales			100			0
Inferæ		0			28	
Rubiales			0			100

The significance of these data may be made still more evident by the following diagrams which are drawn to the same proportions (*fig. 1*).

Attention may well be called to the close agreement between the results reached by Schimper and Lesquereux. According to

Schimper, 96 per cent. of the species are apetalous and choripetalous, and but 4 per cent. gamopetalous, while according to Lesquereux 92 per cent. are apetalous and choripetalous, and 8 per cent. gamopetalous. Again, we find that, according to

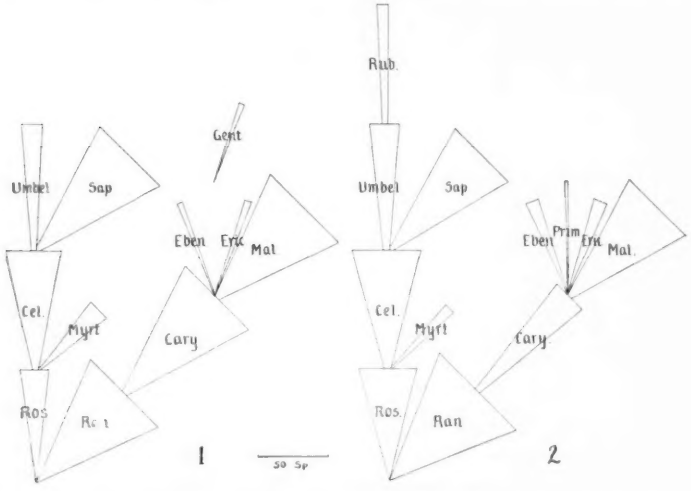


Fig. 1. Diagrammatic comparison of the groups of Cretaceous dicotyledons: 1. according to Schimper; 2. according to Lesquereux. The widths of the triangles indicate relative numbers of species.

Schimper, 80 per cent. of the species have superior ovaries and 20 per cent. inferior ovaries, and these are exactly the proportions in Lesquereux's list. It is worthy of notice, also, that the two lists agree almost exactly in the sub-orders represented, and in the relative number of species in each. Thus in the Thalamifloræ in both lists the Ranales and Malvales are more numerously represented than are the Caryophyllales; in the Calycifloræ, the parallelism is still more marked, the lowest numbers occurring in both lists in Myrtales and Umbellales, intermediate numbers in Rosales, and the highest in Celastrales and Sapindales.

In one particular there is a marked difference between the two lists. Schimper's contains 64 per cent. of apetalous plants, with

but 36 per cent. of those having petals, while Lesquereux's list contains but 42.5 per cent. of apetalous, and 57.5 per cent. of petalous plants. This result is so directly contrary to the commonly accepted notions as to the composition of the dicotyledonous flora of the Cretaceous period that it is worthy of careful consideration. It is possible that this unexpected predominance of the petalous plants is merely the result of the more careful and exhaustive study of the Cretaceous fossils of America, and that when we know more fully the fossil plants of the Cretaceous elsewhere we shall no longer suppose the earlier dicotyledons to have been mainly apetalous. The suggestion is seen to be quite probable when we observe that Lesquereux's earlier report[6] contained 61 per cent. of apetalous to 39 per cent. of petalous plants. Here very certainly the work of twelve or fourteen years upon one formation reversed the numerical proportions between the apetalous and the petalous plants.

In the Eocene period, if we follow Schimper, we find that the families of dicotyledons had risen from twenty-one in the Cretaceous to forty, and that the species were more than three and and one-half times as numerous. The gamopetalous species had risen to 14 per cent., and of the remainder considerably more than one half (57.5 per cent.) were petalous. For the whole of the dicotyledons the per cent. of petal-bearing species had risen to nearly 64. And yet in spite of all this increase we find that the per cent. of species with inferior ovaries remained as in the Cretaceous, or nearly so.

Many families were added in the sub-orders previously represented, and some new sub-orders appeared. Thus in Ranales there were added the Anonaceæ and the Nymphæaceæ. The sub-orders Polygalales and Geraniales appeared, the first represented by the Pittosporaceæ, and the second by the Rutaceæ. To the Malvales were added the Sterculiaceæ and Tiliaceæ; to the Rosales, the three leguminous families (Mimosaceæ, Cæsalpiniaceæ, and Papilionaceæ); to the Celastrales, the Ilicineæ, Celastraceæ, Rhamnaceæ, and Thymelæaceæ; to the Umbellales,

[6] The Cretaceous Flora. U. S. Geol. Survey of the Territories. 1874.

the Cornaceæ; to the Ebenales, the Sapotaceæ, and Styracaceæ; and to the Gentianales, the Oleaceæ, and Apocynaceæ. The suborders Primulales (with Myrsinaceæ 6), Polemoniales (with Convolvulaceæ 2 and Solanaceæ 1), Rubiales (with Caprifoliaceæ 4), and Asterales (with Compositæ 1) complete the list of additions, and give us a hint as to the method of evolution.

Miocene dicotyledons included 66 families, and the species were more than seven times as many as in the Eocene. Here the petalous plants constituted 64 per cent. of the whole, of which nearly 16 per cent. were gamopetalous. The great increase in the number of species was accompanied by a rapid multiplication and modification of previously existing types. Thus we find three more families added to Ranales, three to Caryophyllales, one to Geraniales, three to Malvales, three to Myrtales, one to Sapindales, one to Umbellales, one to Polemoniales, two to Gentianales, and one to Rubiales. The Parietales, Guttiferales, Personales, and Lamiales appear here for the first time. A closer examination of Schimper's list of Miocene plants indicates that in passing from the Eocene to the Miocene, the percentage of species of Ranales was not changed, while that of the Caryophyllales was increased, the Malvales decreased, the Primulales unchanged, the Ericales decreased, the Ebenales slightly increased, the Rosales unchanged, the Myrtales, Celastrales, and Sapindales slightly increased, the Umbellales decreased, the Rubiales and Asterales increased. If we examine the dicotyledonous vegetation of the earth today we may observe that to a limited degree these tendencies to increase or decrease are maintained to the present. This is shown in detail in the following tables (see page 153).

These facts are still more suggestive when presented in diagrammatic form (*fig.* 2, page 154).

After making due allowance for the imperfection of the palæontological record, and our limited knowledge concerning it, it is still safe to say that earlier dicotyledons were of considerably different types from the later, and that from period to period the relative numbers of higher types were increased.

PERCENTAGES OF SPECIES BY SUB-ORDERS.

	Cretaceous		Eocene Schimper	Miocene Schimper	Present Durand
	Lesquereux	Schimper			
Ranales	21.0	18.0	8.0	8.0	3.7
Polygalales	....	....	1.2	0.2	0.9
Caryophyllales	7.0	17.0	3.0	4.0	5.0
Geraniales	....	....	1.2	2.3	5.0
Malvales	16.0	18.0	18.0	9.2	9.8
Rosales	11.6	5.5	11.0	11.0	11.0
Myrtales	1.9	4.4	2.1	2.7	7.5
Celastrales	14.0	11.0	15.1	15.4	5.0
Sapindales	14.7	16.0	22.0	24.5	2.6
Umbellales	6.0	4.4	7.0	2.3	2.3
Primulales	2.2	....	1.8	1.8	1.6
Ericales	2.5	1.1	6.0	3.5	2.1
Ebenales	2.5	1.1	3.0	3.6	1.1
Polemoniales	....	....	0.9	4.3	4.9
Gentianales	....	1.1	0.9	3.5	5.0
Personales	....	....	....	0.4	7.0
Lamiales	....	....	....	0.1	4.5
Rubiales	....	....	1.2	1.5	6.0
Asterales	...	....	0.3	0.9	13.5

PERCENTAGES OF SPECIES BY LARGER GROUPS.

	Cretaceous[7]			Eocene Schimper	Miocene Schimper	Present Durand
	Lesq'x (1)	Lesq'x (2)	Schimper			
Apetalous	61.0	42.5	64.0	36.3	36.0	15.5
Polypetalous	34.0	49.5	32.0	49.6	48.0	36.0
Gamopetalous	5.0	8.0	4.0	14.0	16.0	48.5
Thalamifloræ	54.7	44.0	55.0	30.0	23.5	27.8
Calycifloræ	40.5	48.0	42.0	56.0	58.6	29.5
Heteromeræ	4.7	5.5	2.0	10.7	9.0	4.4
Bicarpellatæ	....	....	1.0	1.8	4.6	10.2
Inferæ	....	2.2	....	1.5	2.5	19.1
Ovary superior	86.8	80.0	80.0	75.4	78.7	65.0
Ovary inferior	13.2	20.0	20.0	24.6	21.3	35.0

[7] For comparison I have given Lesquereux's results in his "Cretaceous Flora" (1), and Flora of the Dakota Group" (2), in addition to Schimper's data. The data for the last column were taken from Durand's "Index Generum Phanerogamarum."

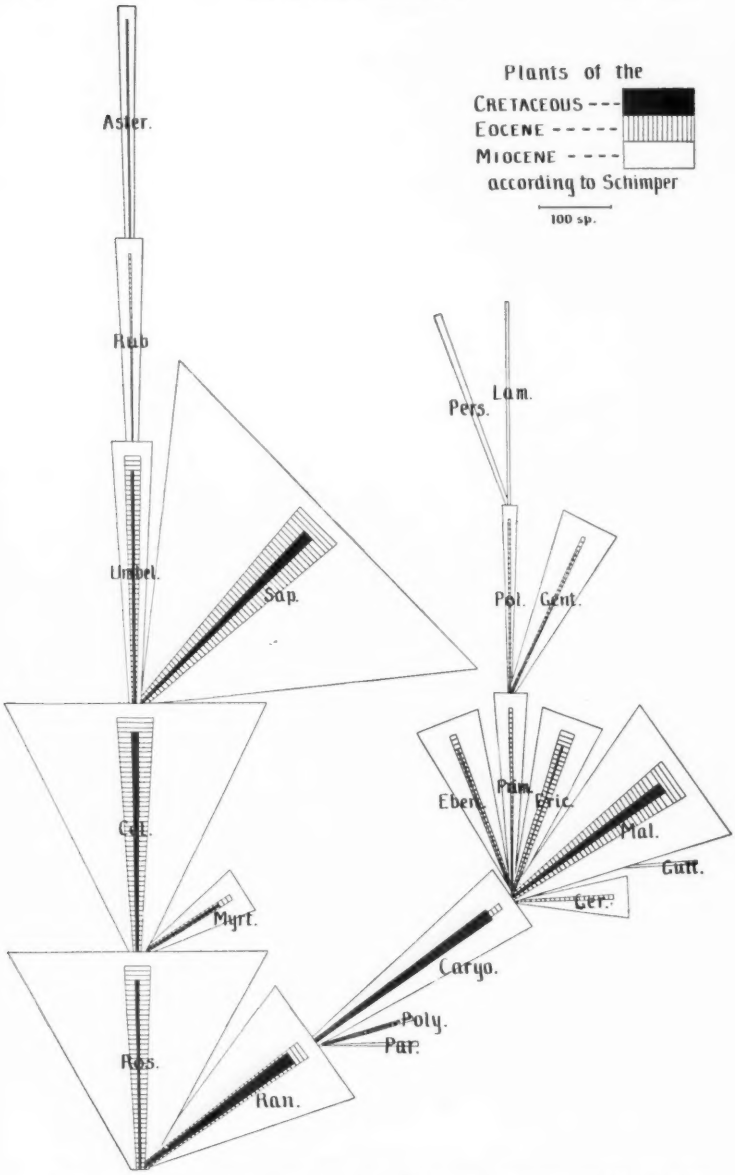


Fig. 2. Diagrammatic comparison of the Cretaceous, Eocene, and Miocene dicotyledonous floras. The widths of the triangles indicate the number of species.

The results of a study of the plants of the Cretaceous, Eocene, Miocene, and the present may be summarized as follows:

1. It is probable that monocotyledons and dicotyledons appeared at about the same time, namely early in the Mesozoic or late in the Palæozoic.

2. The hypogynous monocotyledons appear to have preceded the epigynous monocotyledons, and similarly the petaloideous hypogynous species seem to have somewhat preceded the spadiceous and glumaceous species.

3. Apparently the Thalamifloræ and Calycifloræ are the two earlier types of the dicotyledons.

4. In the Thalamifloræ the three sub-types Ranales, Caryophyllales, and Malvales appear to be earlier than Parietales, Polygalales, Geraniales, and Guttiferales.

5. In the Calycifloræ the Rosales, Celastrales, and Sapindales are the dominant sub-types; here the second and third are greatly reduced in passing to the present, while the first maintains its position with singular persistence.

6. The Myrtales appear to be a growing sub-type, increasing rapidly in passing to the present.

7. The Umbellales, on the other hand, appear to be a waning sub-type.

8. The Heteromeræ have always been of secondary importance.

9. The Bicarpellatæ and Inferæ appear to have developed later than the other types, and to have rapidly increased to the present.

10. In the development of the Bicarpellatæ the Polemoniales and Gentianales preceded the Personales and Lamiales.

11. In the Inferæ the Rubiales led the Asterales.

12. "Polypetaly" appears to have been the common condition in the Cretaceous, Eocene, and Miocene periods.

13. The first modification from polypetaly probably was in the direction of apetaly, a condition reached by many plants in the earlier periods, but by relatively smaller numbers in the present

14. Gamopetaly, from small beginnings, has increased rapidly to the present.

15. Hypogyny has measurably decreased, while epigyny has correspondingly increased.

GENERAL RESULTS FROM EMBRYOLOGY (ONTOGENY.)

After fertilization, the oosphere in all angiosperms divides transversely into two parts, one of which becomes the so-called "suspensor," and the other the embryo proper. The suspensor segment may remain undivided, or it may undergo one or more divisions. The embryo segment at once, or after one or more longitudinal divisions, becomes divided by a transverse wall which separates the foliar (terminal) from the cauline (central) cell or cells. Soon walls form parallel to the surface of the growing embryo, giving rise to a distinct outer layer, the dermatogen, which covers all except the lowermost part of the growing plant. A little later the inner cells of the cauline portion become differentiated into plerome and periblem. Finally, the formation of the root and the root-cap are essentially the same in all angiosperm embryos.

The development of the embryo is so nearly the same in the two sub-classes, that we are compelled to admit their close relationship. The only histological difference which is measurably constant is that the longitudinal division of the embryo takes place before the formation of transverse walls in dicotyledons, and afterwards in the monocotyledons. To this general rule, however, there are numerous exceptions.

If we study the subsequent development of the embryo it is found that the terminal cell, which remains for some time undivided, usually produces a single foliar structure (cotyledon) which is situated terminally upon the caulicle, and that the terminal cell which undergoes early longitudinal division gives rise to two foliar structures (cotyledons). Whether the formation of one or two cotyledons is dependent upon the direction of the separating walls cannot be discussed here. It is at least an interesting coincidence that in the young embryo the undivided

foliar cell gives rise to the single cotyledon, and the divided cell, to the pair of cotyledons.

Thus far in this discussion the embryology of monocotyledons and dicotyledons indicates little more than the close relationship of the two sub-classes. Will it do more? Are there any indications which may help us to answer the question of the origin of these two groups? Have dicotyledons been derived from monocotyledons, monocotyledons from dicotyledons, or both from some common ancestor? It must be admitted that on theoretical grounds it is no more difficult to pass from two cotyledons to one, than from one to two. Indeed, there have been not a few botanists who have suggested the derivation of the monocotyledons from the dicotyledons. When, however, one compares the two embryos, there is a slight preponderance in favor of the view that the structure is a little higher in dicotyledons than in monocotyledons. The row of undivided cells in the embryo of the monocotyledon after the third or fourth segmentation is certainly a lower structure than the compact mass of cells constituting the "octant-stage" of the dicotyledonous embryo. The cotyledons themselves afford a slight suggestion as to the relationship of the two groups. It is a well established principle in embryology that embryonic stages of higher organisms resemble the adult stages of the organisms which are lower in the same genetic line. Applying this principle to the cotyledons, we observe that while they bear some similarity to the leaves of both monocotyledons and dicotyledons, the similarity is a little more marked in case of the monocotyledons. Compare the mostly sessile, often clasping, usually elongated leaves of monocotyledons with the cotyledons of either class, and contrast these with the mostly petioled, generally not clasping, and usually broad-bladed leaves of the dicotyledons.

But we must not stop with the embryo plant in this comparison. The young plant continues to pass through what are essentially embryonic stages long after it has left the seed, and begun its life as an independent organism. In the ontogeny of

a plant there is no sharp line separating its embryonal from its subsequent life, and in the study of the development of the individual in order to make out the course of development of the species, we must follow its whole life from its beginning to its maturity. The leaves of dicotyledons present an interesting study from this standpoint. It is a well-known fact, as pointed out by Lubbock,[8] that the earlier leaves are generally quite different from the later. In the young plant of the field buttercup of Europe (*Ranunculus arvensis*), for example, the leaves of the first node (cotyledons) are obovate or slightly spatulate; the second leaf, round-cuneate and five-toothed; the third, broadly obovate-cuneate with five large teeth; the fourth, three-parted, the divisions cuneate and three-toothed; the fifth, three-parted, the divisions cuneate, narrower below and four to five-toothed above; the sixth, three-parted, the terminal division irregularly three-lobed, the lateral divisions deeply two-parted, all the subdivisions toothed; the seventh, three-parted, the terminal division again three-parted, the lateral divisions two-parted, all the subdivisions narrow and more or less deeply and narrowly lobed. Here the earlier leaves suggest the mature foliage of *Ranunculus abortivus*, *R. pygmæus*, *R. pedatifidus*, *R. pusillus*, *R. hyperboreus*, and others. It does not require much study to convince one, after an examination of Lubbock's descriptions, that the young plants of different species of Ranunculus are much more alike than are the mature plants. And it is a familiar fact to those who have watched the growth of seedlings of all kinds that in general they resemble one another most when youngest, and that this resemblance becomes less and less as the plants become older. For many seedlings one can do no more when they first appear than to recognize the sub-class to which they belong; a little later the family characteristics may be made out; still later the genus is recognized; while it often happens that we must wait for the flower or even the fruit before we are able to certainly recognize the species. Sow seeds of a buttercup (Ranunculus), a clematis (Clematis), a potentilla (Potentilla),

[8] On seedlings 2, 75, *et seq.* 1892.

a cucumber (Cucumis), a sunflower (Helianthus), a water-plantain (Alisma), an arrow-head (Sagittaria), a lily (Allium), an oat (Avena), and a wheat (Triticum), and when the young plants first appear they will be recognized merely as five dicotyledons and five monocotyledons. But a little later the buttercup, clematis, and potentilla will separate themselves from the cucumber and sunflower, the former resembling one another very much, and having a common buttercup-like look, while the latter resemble one another nearly as much. The families to which the seedlings belong will be indicated next, but it will take longer to separate the potentilla from the buttercup and clematis than the cucumber from the sunflower. The buttercup and clematis will be generically indistinguishable much longer, and had we planted seeds of different species of one of these it would have been still longer before differential characteristics would have appeared. So too with the monocotyledons, the families can be recognized long before the genera, and the genera long before the species.

Now what do these facts indicate? How can we make use of them in our present inquiry? Is it not highly probable that they indicate how and when the differentiation of species from species, of genus from genus, of family from family occurred? If we grow two plants side by side and find them to be indistinguishable until they have formed their fruits, are we not warranted in regarding the relationship a very close one, and may we not safely assume that the separation is a relatively recent accomplishment? There can be no valid objection to the rule that the greater the number of stages of identical development between plants the closer the relationship. This is but another way of expressing the common working rule of botanists that close relationship is shown by the identical structure of many organs. When we know the life history (ontogeny) of a group of plants, and have brought these together so that we shall have well wrought out the comparative ontogeny of all the species, we shall be able to indicate with much exactness their mutual relationship. And when this is done for all of the

groups of angiosperms, their mutual relationship, also, will be indicated.

The most important suggestions as to relationship which have thus far presented themselves in embryology (ontogeny) may be summarized as follows:

1. All angiosperms are essentially alike.

2. The two sub-classes (monocotyledons and dicotyledons) appear to be modifications of a common type which diverged from one another at an early period.

3. There is no indication that either sub-class was derived from the other.

4. There are some structural indications that the monocotyledons must rank lower than the dicotyledons.

5. The vegetative rank of most dicotyledons is so nearly the same as to have left no vestiges on the young plant, which is itself vegetative.

6. The groups into which dicotyledons and monocotyledons are divided are "flower-subdivisions" of a greatly multiplied, rather common vegetative structure; therefore, we may not expect to find upon the embryo or immature plant any vestigial record of their origin.

7. There are some minor structural modifications, as of leaf-shapes, serration, lobing, etc., which appear to have arisen late in the history of the species, and therefore serve as indices of specific and sometimes generic relationship.

GENERAL RESULTS FROM MORPHOLOGY.

Modern morphology concerns itself so largely with the comparative development as well as the comparative anatomy of organs as to make it impossible to draw a sharp line between it and ontogeny. It is by studying the development of organs in the immature plant, from the smallest rudiments to their full growth, that we have been able to make out their homologies. Morphology must include all of embryology and all of ontogeny.

It is needless here to take up in detail the morphology of the cells and tissues of angiosperms. It is enough to remark in

passing that these present similar diversity of form and function in both sub-classes, and that from this fact we may infer the close relationship, if not the common origin of the monocotyledons and dicotyledons.

The tissue systems present no constant differences in the boundary and fundamental systems. Possibly the surface appendages (trichomes) reach a higher development in some dicotyledons than in any monocotyledons. The skeletal system shows some well marked differences. In monocotyledons the fibrovascular bundles are typically separate, while in dicotyledons they are typically united with one another. In the former each bundle is complete in itself, and is often sharply defined by a bounding layer of cells, while in the latter the bundles form parts of an aggregation in which the limits of the individual bundles are often indistinguishable. The shorter life of the bundle in the monocotyledons contrasts sharply with its longer life in most dicotyledons, sometimes reaching hundreds of years, as in the long-lived oaks and chestnuts. And yet these differences, sufficiently constant to characterize the sub-classes, are not invariable. There are skeletal systems in some dicotyledons whose bundles are separate, short lived, and incapable of continued growth, showing again the close relationship of the two sub-classes.

The organs of the plant body present great diversity, and their morphology has long been the subject of much study by many investigators. They may be reduced to the following types: roots, stems, foliage leaves, flower leaves, pollen leaves, ovule leaves.

Roots.—The young roots of monocotyledons are structurally simpler than those of dicotyledons. They rarely increase much in thickness or endure for any great length of time, and are usually unbranched. They contain a single central fibrovascular bundle. The roots of dicotyledons when young contain a single central bundle, but they generally develop several collateral bundles, and are thus able to increase in thickness and to endure for an indefinite time. They are commonly branched again and

again. Here we have as a temporary condition in dicotyledons the structure which is permanent in monocotyledons.

Stems.—The young stems of monocotyledons and dicotyledons differ less than do the old stems of these sub-classes. In young stems of dicotyledons the skeletal system is composed of separate fibrovascular bundles which traverse the parenchymatous ground tissue, and at this stage the hypodermal tissues are not unlike, either in composition or arrangement. In herbaceous stems this similarity is maintained much longer than in woody stems, where the dissimilarity eventually becomes extreme. The important difference between these two types of stems is that the skeletal tissues combine to form a single solid column in the dicotyledons, while they do not in the monocotyledons. Now when to this we add the fact that the bundles of dicotyledons have fused in such a manner that their continued growth adds to the mass of the skeletal column, thus giving to the stem the possibility of indefinite increase in mass, we have again an indication of the higher rank of this sub-class.

In regard to external morphology it may be remarked that in monocotyledons there are two well defined modifications of the normal type of vegetative stem, as seen in lilies, naiads, orchids, etc. One extreme of this modification occurs in the grasses and sedges in which the internodes are greatly elongated, and the other in palms and screw-pines, in which the internodes are usually so short as to be scarcely recognizable. The suggestion which these stem modifications offer as to the relationship of grasses and sedges on the one hand, and palms and screw-pines on the other, to the lilies is obvious.

Leaves.—In general structure the leaves of angiosperms are essentially alike. The significant differences may be enumerated as follows:

1. The leaves of monocotyledons are usually entire, elongated, parallel-veined blades, placed alternately or scattered upon the stem, to which they are attached directly (in sessile leaves) or indirectly (in petioled leaves) by a commonly broad base which is rarely supplied with stipules.

2. The leaves of dicotyledons are entire or more commonly dentate or lobed, usually broad, netted-veined blades, opposite, alternate, or scattered upon the stem, to which they are usually attached indirectly (petiolate) by a narrow base (rarely by a broad base), which is commonly supplied with stipules.

These structural differences are mainly due to differences in development. The parallelism of venation and the general absence of lobing in the leaves of monocotyledons result from the localization of growth at the base of the blade or in definite bands on each side of its axis, and commonly the netted venation in the leaves of dicotyledons results from the longer continued and more or less irregular growth of all parts of the blade; and it is to this irregularity of growth, also (especially in the peripheral portions), that the serrations, dentations, lobings, etc., are due. The development of a petiole is correlated with the assimilatory function of the leaf, and in both sub-classes is less or more, according to the degree of its illumination. The broad basal attachment in monocotyledons may depend upon the looser disposition of the fibrovascular bundles in the stems, or possibly it may indicate that leaf and stem are not yet as fully differentiated as they are in dicotyledons, a view which receives some confirmatory suggestion from the presence of an articulation at the base of the leaf in most dicotyledons, while it is absent from most monocotyledons. The significance of the stipules is not so obvious; probably their more frequent occurrence in dicotyledons is correlated with the more common development of the petiole in this sub-class.

The particular morphology of leaves is commonly indicative of relationship between species and genera, and now and then it has a broader significance. In the monocotyledons the common type of leaf is particularly modified in the sedges and grasses, this modified type being maintained with great constancy throughout the two great families. Among dicotyledons the greatly branched ("compound") leaves of mimosas (Mimosaceæ), brasilettos (Cæsalpiniaceæ), sumachs (Anacardiaceæ), walnuts (Juglandaceæ), and umbellifers (Umbelliferæ) are characteristic

of the families, and so too are the opposite leaves of the verbenas (Verbenaceæ), mints (Labiatæ), honeysuckles (Caprifoliaceæ), and madderworts (Rubiaceæ).

Flower leaves.—The reproductive strobilus of angiosperms consists of a stem upon which are developed spore-bearing and sterile leaves. Whether the sterile leaves were originally derived from the spore-bearing ones by a process of sterilization, as suggested by Bower,[9] need not be discussed here, since such sterilization, if it ever occurred, must have taken place long before the ancestors of the angiosperms crossed the line which separates the Pteridophyta from the Spermatophyta. We have here to deal with the reproductive strobilus in the form of the flower, in which the sterile leaves are well set off from those which bear spores.

In the simpler cases the sterile leaves (perianth) are separate from one another, and this doubtless represents their primitive structure. In other cases the flower leaves have fused more or less in their growth, this doubtless being a structure derived from the simple primitive condition referred to above. In many flowers the perianth leaves show no differentiation from one another, while in others they are very unlike. In this matter it is reasonable to suppose that the primitive flower leaves were at least approximately alike in form and dimensions, and that unlikeness in these particulars arose as a modification of the primitive structure. Again we find that in many flowers the sterile leaves are in no way connected with the spore-bearing leaves, the former being attached at a distinctly lower level upon the stem. In other cases, however, there is more or less union between the sterile and spore-bearing leaves, in extreme cases amounting to complete fusion. Here again it is not hard to recognize in united and fused leaves a structure derived from the more primitive free leaves. This union of parts may receive the general designation of *symphysis*.[10]

Some flowers have a scanty perianth (apetalous) and others,

[9] A theory of the strobilus in archegoniate plants. Ann. Bot. **8**: 343. 1894.

[10] Greek *σύμφυσις*, a growing together, natural joining.

again, none at all (naked). Since these often occur on plants which are clearly related to those bearing a fully developed perianth, we are led to the conclusion that apetalous and naked flowers are modifications of the common flower structure. Thus, there can be no question as to the relationship of Clematis, Anemone, Thalictrum, Caltha, Hydrastis, etc., to Ranunculus, Myosurus, Coptis, Delphinium, and other genera of Ranunculaceæ. So, too, who questions the relationship of our apetalous maples (*Acer saccharinum* L. and *A. negundo* L.) to the remaining species of the genus, or of our ashes (Fraxinus sp.) to the old world petalous species? In these and many other cases we see clearly that the apetalous condition of the flower is one derived from the normal structure in which the complete perianth is present. There are, however, many apetalous dicotyledons whose relationship botanists have not been able to agree upon. Thus Bentham and Hooker in their *Genera Plantarum* enumerate thirty-six families, including 849 genera, and 12,100 species, in the artificial group Monochlamydeæ, which they separate from their Polypetalæ solely by the simple (or absent) perianth; Engler and Prantl in their *Pflanzenfamilien* bring together into a heterogeneous group twenty-four families of mostly apetalous plants, including nearly 6000 species. All of these, excepting the Olacaceæ, are included in Bentham and Hooker's Monochlamydeæ, so that we have in Engler and Prantl's arrangement a reduction of Monochlamydeæ amounting to fully one-half. This has been accomplished by a distribution of apetalous plants among those whose flower structure differs only in regard to the perianth. That this reduction could have been carried further without doing violence to our knowledge of relationship will be admitted by most systematic botanists. Thus we may readily remove the Olacaceæ, which have a perianth consisting of calyx and corolla, and with them may go the sandalworts (Santalaceæ), proteads (Proteaceæ), loranths (Loranthaceæ), and perhaps the balanophorads (Balanophoraceæ), all of which are more or less clearly related to the typical Celastrales. So too the willows and poplars (Salicaceæ) differ from the tamarisks (Tamaricaceæ) only

in the absence of a perianth, the "gynæcium, placentation, ovules, fruit and seeds agreeing completely," as pointed out by Niedenzu[11] in his discussion of the relationship of Tamaricaceæ.

If we were to suggest a natural classification of the dicotyledons based upon the morphology of the sterile flower leaves alone, we should group together first those plants with all their flower leaves free from one another; this would constitute our primitive group. In another place we should bring together all those in which the sterile and spore-bearing flower leaves have undergone the greatest fusion; this would constitute our highest group. Between these we should have to arrange the intermediate conditions. Then remembering that the perianth readily becomes much reduced we should have to give such place and position to each apetalous plant as its structure otherwise demanded.

Pollen leaves (microsporophylls, stamens).—The normal position of these is between the sterile and the ovule leaves. In many cases they are quite separate from one another and from the other leaves of the flower, but in many other cases they are united to one another, or to the leaves below or above.

Numerically the pollen leaves show great diversity. This is correlated with the greater or less amount of pollen required to insure the production of seeds in the different species. In general, no organs of the flower exhibit so little constancy in structure, dimensions, number, or position as the pollen leaves, and yet within narrow limits these inconstant organs often present a surprising conformity to a single type. They serve well, therefore, to define the smaller groups, but have little value as indicating broader relationships.

Ovule leaves (macrosporophylls, carpels).—These occupy the highest portion of the strobilus, and are normally separate organs, unconnected with one another or with other organs. In buttercups (Ranunculaceæ), potentillas (Rosaceæ), and water-plantains (Alismaceæ) the carpels are many and separate, while in pinks (Caryophyllaceæ), saxifrages (Saxifragaceæ), and lilies (Liliaceæ) they are more or less united with one another, thus

[11] ENGLER and PRANTL. Die Natürlichen Pflanzenfamilien 3^6: 291.

forming a single syncarpium, the so-called "compound pistil" of descriptive botany. Many syncarpia still preserve some of their parts free from one another; thus in the saxifrages, most pinks, and some lilies, the carpels are united for only a part of their length, the terminal portions (styles) being free, while in myrtles (Myrtaceæ), primroses (Primulaceæ), and spiderworts (Commelinaceæ) they are fully united from end to end. All apocarpia are free from the other organs of the flower, and this is the case with many syncarpia. There are, however, many syncarpia to which some or all of the other leaves of the reproductive strobilus have become more or less completely attached. In the so-called epigynous flowers, as the irids and orchids among the monocotyledons, and the myrtles, cactuses, umbelworts, and all of the Inferæ of the dicotyledons, there has been such a fusion of the originally separate parts of the strobilus as to result in a single compact structure in which in extreme cases only the distal portions of the original leaves are distinguishable.

The primitive syncarpia of the monocotyledons appear to have contained three carpels, as in lilies, and those in dicotyledons five or more, as in pinks and mallows. In the fusion of the parts of the strobilus some of these are usuàlly suppressed. As a result we find that in case of the greatest fusion the syncarpium contains fewer than the normal number of carpels, as for example, in the Asterales of the dicotyledons, where there are but two carpels remaining, and these so reduced as to function as but one. The genetic line which includes pinks (Caryophyllales), primroses (Primulales), phloxes (Polemoniales), figworts (Personales), and mints (Lamiales) illustrates this tendency to a reduction in the number of parts with increased fusion of the strobilar leaves. The same law is illustrated in the genetic line which includes the lilies (Coronarieæ), pipeworts (Eriocaulaceæ), sedges (Cyperaceæ), the lower grasses (Bambuseæ), and higher grasses (Agrostideæ and Paniceæ); or possibly still better in the line from lilies to amaryllids (Amaryllidaceæ), irises (Iridaceæ), burmannias (Burmanniaceæ), and orchids (Orchidaceæ).

It will be seen from the foregoing discussion of the reproductive strobilus that there are two principal modifications to which it is subject, namely (*a*) *symphysis*, that is, a fusion of parts, and (*b*) *aphanisis*,[12] a suppression of parts. These may separately or jointly affect some or all parts of the strobilus, resulting in the multitude of forms which it assumes. Aphanisis alone results in apetaly and diclinism; symphysis alone, in such a type as we find in myrtles and cactuses.

We may summarize the results from a morphological study of plants as follows:

1. The identity of the cells and tissues of the two sub-classes of angiosperms indicates their close relationship.

2. The fibrovascular tissue-system of the dicotyledons indicates that this sub-class is higher than the monocotyledons.

3. The roots of dicotyledons indicate that this sub-class is higher than monocotyledons, and suggest the possibility of the origin of the former from the latter.

4. The structure of the dicotyledonous stem indicates the higher rank of this sub-class.

5. Among monocotyledons the external morphology of the stem indicates the derivation from lily-like plants of the palms and screwpines by an excessive shortening of internodes, and of sedges and grasses by a corresponding elongation.

6. The general morphology of the leaves of monocotyledons and dicotyledons, as has already been indicated many times, emphasizes the close relationship of the two sub-classes, and repeats the suggestion that the former include plants which must take rank below the dicotyledons.

7. The particular morphology of leaves commonly indicates specific or generic relationship, but now and then they possess a sufficient constancy to serve as indices of family relationship.

8. There are two principal modifications of the flower strobilus—namely, symphysis and aphanisis—which separately or jointly affect some or all of its parts.

[12] Greek ἀφάνισις, a getting rid of, a vanishing, a disappearance.

9. The perianth of separate leaves becomes modified by their fusion with one another and with other strobilar leaves (symphysis). The reduction (aphanisis) of the perianth is a modification of much less morphological significance, and is rarely, if ever, indicative of broad relationships.

10. The pollen leaves show constancy in structure, dimensions, number, and position only within narrow limits, and therefore serve to define the smaller groups (families and tribes), but have little value as indices of broad relationships.

11. In the symphysis of the primitive apocarpous flower strobilus the carpels first unite into a syncarpium, and with this process of fusion there is generally a progressive reduction (aphanisis) in the number of constituent carpels.

12. The extreme modification of the flower strobilus results in the fusion of all the constituent parts (symphysis) and their reduction in number (aphanisis).

From all the foregoing we may pretty safely proceed to construct the hypothetical phylogeny of the angiosperms, to serve as the basis of their taxonomy. And let it be fully understood that this is not presented as final, or as entirely satisfactory; it is merely a working hypothesis, which claims no other merit than that of an attempt at conformity to the suggestions sometimes faint, sometimes doubtful, from palæontology, from embryology (ontogeny), and from morphology. That some of these suggestions have been misinterpreted, or that others have been overlooked, is altogether likely; but in this I must beg the indulgence of systematists, who may well realize the difficulties surrounding the problem here undertaken.

HYPOTHETICAL PHYLOGENY OF ANGIOSPERMS.

The angiospermous phylum parted very early into two subclasses, the monocotyledons and dicotyledons. This separation took place while the flower strobilus was still apocarpous, and before any of the strobilar leaves had undergone much, if any, modification. At this stage the vegetative characters of the

sporophyte were so well established that no profound modifications have been undergone since.

The modifications which gave us the main lines of monocotyledons were first the fusion of the carpels with one another and the production of a syncarpium, and second the progressive fusion of the syncarpium with the other strobilar leaves. These resulted in the phylum which begins with Apocarpæ and passes to Coronarieæ, Epigynæ, and Microspermæ. In some Apocarpæ and many plants of the type of the Coronarieæ the perianth has been more or less reduced (by aphanisis), in some cases amounting to complete suppression, as in palms (Calycinæ), aroids (Nudifloræ), and sedges and grasses (Glumaceæ).

The primitive dicotyledons were apocarpous plants which soon developed along two diverging lines, characterized in the one case by the tendency of the leaves of the strobilus to fuse with each other in a transverse direction (transverse symphysis), while in the other the tendency was to a fusion of the leaves in two directions (transverse and longitudinal symphysis). The phylum resulting from the predominance of transverse symphysis began with the apocarpous Ranales, soon developing into the syncarpous Caryophyllales and Malvales. The type of the Caryophyllales became slightly modified in the Primulales by the transverse symphysis of the inner perianth whorl resulting in gamopetaly. In the Polemoniales the type of the Primulales began to undergo modification by aphanisis, resulting in a reduction of the microsporophylls to five, and the carpels in the syncarpium to two or three. Increasing aphanisis produced the Personales and Lamiales with their four or two microsporophylls and irregular perianth, and in the latter group with each carpel restricted to the production of but one or two macrosporangia.

The phylum in which both transverse and longitudinal fusion are well marked proceeds from the apocarpous roseworts (Rosaceæ) to the syncarpous saxifrages (Saxifragaceæ) of the Rosales, to the Celastrales, in which epigyny is sometimes attained, thence to the Umbellales, where epigyny is constant, and to the Rubiales, in which gamopetaly has become a fixed

character, culminating in the group of the Asterales with its greatly reduced bicarpellary syncarpium.

Early predominance of aphanisis in the ranal phylum soon gave rise to the apetalous laurels (Lauraceæ) and nutmegs (Myristicaceæ) from the buttercup type. A somewhat later appearance of aphanisis gave rise to the willows (Salicaceæ), amaranths (Amaranthaceæ), and buckwheats (Polygonaceæ) from the pink type; and the spurgeworts (Euphorbiaceæ) and nettle-worts (Urticaceæ) from them allow type. Similarly, early predominance of aphanisis in the rosal phylum gave rise to the apetalous plane-trees (Platanaceæ) from the rosewort type; while its later appearance gave rise to the proteads (Proteaceæ), daphnads (Thymelæaceæ), oleasters (Elæagnaceæ), sandalworts (Santalaceæ), and loranths (Loranthaceæ) from the holly type; and the walnuts (Juglandaceæ), oaks (Fagaceæ), and gale-worts (Myricaceæ) from the horse-chestnut type (Sapindales).

Early predominance of symphysis gave rise to the peculiar group of the myrtles (Myrtales) from the rosewort type, in which by later aphanisis, hippurids (Halorageæ), birthworts (Aristolochiaceæ), vine rapes (Cytinaceæ) were produced. The Parietales and Polygalales are later developments more or less parallel to the Caryophyllales; while the Geraniales and Gutti-ferales stand in a similar relation to the Malvales.

THE TAXONOMY OF ANGIOSPERMS.

It should not be necessary to urge at this time the desirability of a conformity between phylogeny and taxonomy, and yet it may be well to call to mind the words of Dr. Gray:

> We have supposed, and Naegeli takes a similar view, that each plant has an internal tendency or predisposition to vary in some directions rather than others; from which, under natural selection, the actual differentiations and adaptations have proceeded. Under this assumption, and taken as a working hypothesis, the doctrine of the derivation of species serves well for the coordination of all the facts in botany, and affords a probable and reasonable answer to a long series of questions which without it are totally unanswerable. It is supported by vegetable palæontology, which assures us that the plants of the later geological periods are the ancestors of the actual flora

of the world. In accordance with it we may explain in a good degree the present distribution of species and other groups over the world. It rationally connects the order of the appearance of vegetable types in time with the grades of differentiation and complexity, both proceeding from the simpler, or lower and more general, to the higher and more differentiated or special; it explains by inheritance the existence of functionless parts; throws light upon the anomalies of parasitic plants in their various gradations, upon the assumption of the most various functions by morphologically identical organs, and indeed illuminates the whole field of morphology with which this volume has been occupied. It follows that species are not "simple curiosities of nature," to be catalogued and described merely, but that they have a history, the records of which are impressed upon their structure as well as traceable in their geographical and palæontological distribution.[13]

In an adjoining paragraph he tersely sums up the matter in this aphorism:

> Affinity under this view is consanguinity, and classification, so far as it is natural, expresses real relationship.

We are warranted in strenuously urging a conformity of taxonomy with phylogeny, and while we must be cautious not to propose a new arrangement for every phylogenetic vagary which may arise, we must be equally careful not to allow our natural inertia, or the conveniences of the art of botany, to retard any change demanded by science.

Four years ago I discussed[14] the insufficiency of the Candollean system, and a year ago that of the system of Engler and Prantl[15] as expressions of genetic relationship. Further study of the problem and of these systems has deepened my conviction that while each is doubtless the best formula of the results of its period, neither one is today an adequate expression of our knowledge of the structure and relationship of the angiosperms. We are not to imagine, however, that the work of the past is to be thrown aside as worthless, and that the system based upon phylogeny will have nothing in common with the older systems. On the contrary, when examined critically,

[13] Structural Botany 330.

[14] Evolution and classification. Proc. A. A. A. S. **42**: 237.

[15] The point of divergence of monocotyledons and dicotyledons. BOT. GAZ. **22**: 229.

the system which seems to us to be more nearly in accord with our knowledge of phylogeny does not differ as much from the two older systems as they differ from one another. It is only when we make a superficial comparison of the Candollean system (as wrought out by Bentham and Hooker) and Eichler's system (as modified by Engler and Prantl) that they seemed to be radically or even greatly different. Engler and Prantl have reduced by one-half that troublesome mass of poorly understood plants, the Apetalæ; then beginning with the Ranales and Parietales a similar sequence of choripetalous groups is taken up in each, this becoming identical near its central course, and towards its culmination in the Umbellales. The only difference in the treatment of the Gamopetalæ is that in order to emphasize relationship with the Umbellales the Inferæ are placed first in Bentham and Hooker's system, while in the system of Engler and Prantl they are placed last, the emphasis here being given to their rank as the highest of dicotyledons.

Bringing together the results of the studies of these masters as shown in their systems, and still better in their discussions of relationship under each family, and using our hypothetical phylogeny as a general guide, we find it possible to make such modifications of the two systems as will give us an arrangement which fairly agrees with the present state of our knowledge.

The angiosperms are separable into two diverging subclasses, the monocotyledons (Monocotyledoneæ) and the dicotyledons (Dicotyledoneæ), the first ranking structurally lower than the second. The monocotyledons are well divided by Bentham and Hooker into seven series, and these we may accept unchanged, with the single exception that the waterworts (Hydrocharitaceæ) should probably be removed from the Microspermæ to constitute an additional coordinate group. These eight groups, which appear to be deserving of no more than ordinal rank, should then be rearranged so as to have the following sequence, namely: Apocarpæ, Coronarieæ, Nudifloræ, Calycinæ, Glumaceæ, Hydrales, Epigynæ, Microspermæ. Here it must be understood that the Nudifloræ, Calycinæ, and Glu-

maceæ are separate orders radiating from the present order Coronarieæ, and that the Hydrales constitute a diverging order from the base of the Epigynæ. The distribution (but not necessarily the exact sequence) of families among the orders may be indicated as follows:

ORDER APOCARPÆ.

Families: Alismaceæ, Triurideæ, Naiadaceæ.

ORDER CORONARIEÆ.

Families: Stemonaceæ, Liliaceæ, Pontederiaceæ, Philydraceæ, Xyridaceæ, Mayaceæ, Commelinaceæ, Rapateaceæ.

ORDER NUDIFLORÆ.

Families: Pandanaceæ, Cyclanthaceæ, Typhaceæ, Aroideæ, Lemnaceæ.

ORDER CALYCINÆ.

Families: Flagellariaceæ, Juncaceæ, Palmaceæ.

ORDER GLUMACEÆ.

Families: Eriocaulaceæ, Centrolepidiaceæ, Restiaceæ, Cyperaceæ, Gramineæ.

ORDER HYDRALES.

Family: Hydrocharitaceæ.

ORDER EPIGYNÆ.

Families: Dioscoreaceæ, Taccaceæ, Amaryllidaceæ, Iridaceæ, Hæmodoraceæ, Bromeliaceæ, Scitamineæ.

ORDER MICROSPERMÆ.

Families: Burmanniaceæ, Orchidaceæ.

The choripetalous and gamopetalous dicotyledons are divided by Bentham and Hooker into six "series," one of which, the Discifloræ, should be broken up and its families distributed elsewhere. The remaining "series," which appear to have the rank of orders, form two somewhat diverging genetic lines or phyla, each beginning with apocarpous, hypogynous, choripetalous plants, and both attaining syncarpy and gamopetaly, one remaining hypogynous, the other becoming epigynous. An attempt has been made to distribute all the apetalous plants, these having been assigned places in the lower two orders.

Since gamopetaly has evidently been attained at more than one point, it is no longer desirable to retain the Gamopetalæ as a distinct group. It must constantly be borne in mind that these orders and their sub-orders, as well as the families, are diversely related to one another, sometimes serially, but more commonly divergently, as the twigs of a tree are related, now by direct extension, and then by lateral branching (see *fig. 3*).

It still remains to work out the particular relationship of the families to one another in the orders of monocotyledons and the sub-orders of dicotyledons, in accordance with the general principles here laid down. This the present writer hopes to complete within the next year or two, having already accomplished somewhat in this direction. This will prepare the way for a natural arrangement of the genera in the families, a task which may well claim many years for its completion.

The distribution (but not necessarily the exact sequence) of the families among the orders may be indicated as follows:[16]

ORDER THALAMIFLORÆ.

Sub-order Ranales.

Families: Ranunculaceæ, Dilleniaceæ, Calycanthaceæ, Magnoliaceæ Anonaceæ, Myristicaceæ, Monimiaceæ, Chloranthaceæ, Menispermaceæ, Berberidaceæ, Lauraceæ, Nymphæaceæ.

Sub-order Parietales.

Families: Sarraceniaceæ, Papaveraceæ, Cruciferæ, Capparidaceæ, Resedaceæ, Cistaceæ, Violaceæ, Canellaceæ, Bixaceæ, Samydaceæ, Lacistemaceæ, Nepenthaceæ.

Sub-order Polygalales.

Families: Pittosporaceæ, Tremandraceæ, Polygalaceæ, Vochysiaceæ.

Sub-order Caryophyllales.

Families: Caryophyllaceæ, > Frankeniaceæ, Tamaricaceæ, Salicaceæ; > Portulacaceæ, Ficoideæ; > Phytolaccaceæ; > Nyctaginaceæ; > Illecebraceæ, Amaranthaceæ, Chenopodiaceæ, Polygonaceæ; > Batideæ (?).

[16] In some sub-orders which have been more exhaustively studied a rearrangement of the families has been made and genetic lines indicated by the sign > which may be read "from whence came," each line being derived from the family first named in the sub-order.

Sub-order Geraniales.

Families: Linaceæ, Humiriaceæ, Malpighiaceæ, Zygophyllaceæ, Geraniaceæ, Rutaceæ, Simarubaceæ, Ochnaceæ, Burseraceæ, Meliaceæ, Dichapetalaceæ.

Sub-order Guttiferales.

Families: Elatinaceæ, Hypericaceæ, Guttiferæ, Theaceæ, Dipterocarpaceæ, Chlænaceæ.

Sub-order Malvales.

Families: Tiliaceæ, >Sterculiaceæ, Malvaceæ; >Urticaceæ, Leitneriaceæ; >Euphorbiaceæ, Balanopseæ, Empetraceæ; > Ceratophyllaceæ, Podostemaceæ; > Piperaceæ.

ORDER HETEROMERÆ.

Sub-order Primulales.

Families: Primulaceæ, > Plumbaginaceæ; > Myrsinaceæ; > Plantaginaceæ.

Sub-order Ericales.

Families: Ericaceæ, > Vacciniaceæ; > Epacridaceæ, Diapensiaceæ; > Clethraceæ, Pirolaceæ, Lennoaceæ.

Sub-order Ebenales.

Families: Sapotaceæ, Ebenaceæ, Symplocaceæ, Styracaceæ.

ORDER BICARPELLATÆ.

Sub-order Polemoniales.

Families: Polemoniaceæ, >Convolvulaceæ; >Hydrophyllaceæ, Boraginaceæ, Solanaceæ.

Sub-order Gentianales.

Families: Oleaceæ, Salvadoraceæ, Apocynaceæ, Asclepiadaceæ, Loganiaceæ, Gentianaceæ.

Sub-order Personales.

Families: Scrophulariaceæ, Orobanchaceæ, Lentibulariaceæ, Columeliaceæ, Gesneraceæ, Bignoniaceæ, Pedaliaceæ, Acanthaceæ.

Sub-order Lamiales.

Families: Myoporaceæ, > Selagineæ; > Verbenaceæ, Labiatæ.

ORDER CALYCIFLORÆ.

Sub-order Rosales.

Families: Rosaceæ, > Connaraceæ, Mimosaceæ, Cæsalpiniaceæ, Papilionaceæ; > Saxifragaceæ, Crassulaceæ, Droseraceæ, Grossulariaceæ, Bruniaceæ, Hamamelidaceæ, Platanaceæ.

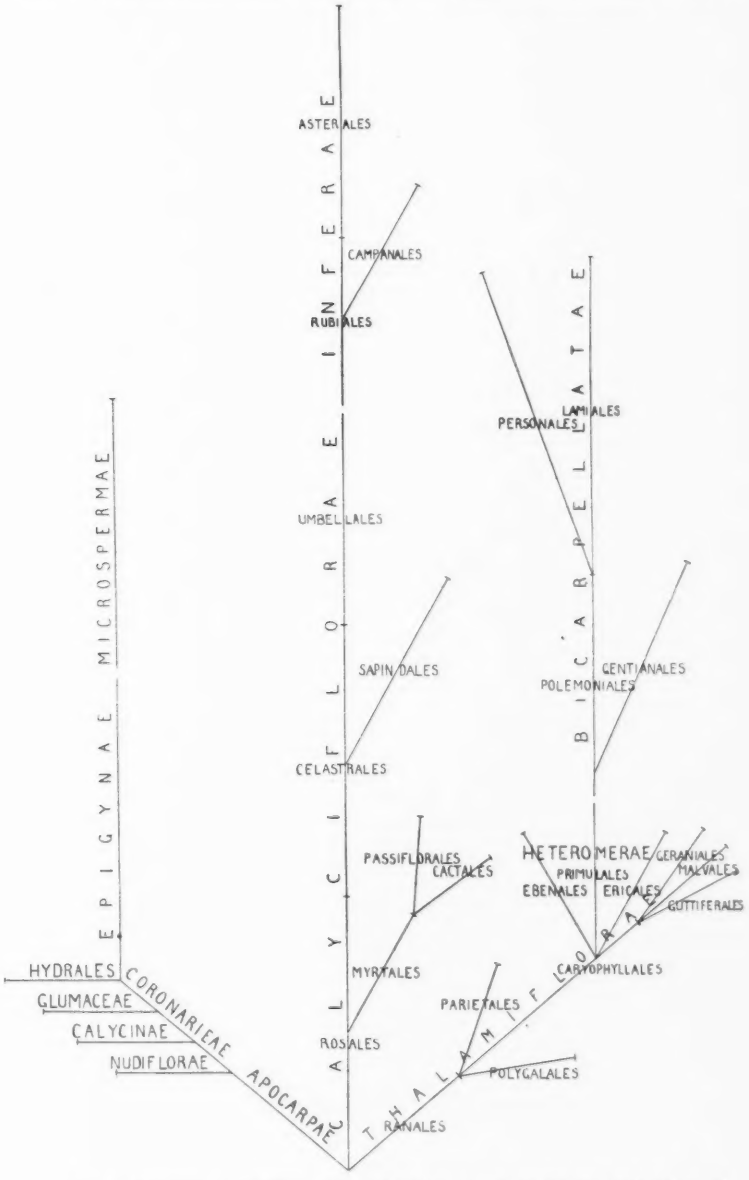


FIG. 3. Diagram to illustrate the relationship of the orders and sub-orders of angiosperms.

Sub-order Myrtales.

Families: Lythraceæ, > Melastomaceæ, Myrtaceæ, Combretaceæ, Rhizophoraceæ; > Onagraceæ, Halorageæ; > Aristolochiaceæ, Cytinaceæ

Sub-order Passiflorales.

Families: Loasaceæ, > Turneraceæ; > Passifloraceæ; > Cucurbitaceæ > Begoniaceæ, Datiscaceæ.

Sub-order Celastrales.

Families: Rhamnaceæ, > Celastraceæ, Stackhousiaceæ, Olacaceæ, Santalaceæ, Loranthaceæ, Balanophoraceæ; > Ilicineæ; > Vitaceæ; > Thymelæaceæ, Elæagnaceæ, Proteaceæ; > Penæaceæ.

Sub-order Sapindales.

Families: Sapindaceæ, > Sabiaceæ, Anacardiaceæ, Juglandaceæ; > Betulaceæ, Fagaceæ; > Myricaceæ; > Casuarinaceæ (?).

Sub-order Umbellales.

Families: Araliaceæ, > Umbelliferæ; > Cornaceæ.

ORDER INFERÆ.

Sub-order Rubiales.

Families: Rubiaceæ; Caprifoliaceæ.[17]

Sub-order Campanales.

Families: Campanulaceæ, > Goodeniaceæ, Candolleaceæ.

Sub-order Asterales.

Families: Valerianaceæ, > Dipsaceæ; > Calyceraceæ; > Compositæ.

THE UNIVERSITY OF NEBRASKA.

[17] It seems probable that the two families of Rubiales originated independently, the Rubiaceæ from Araliaceæ, and the Caprifoliaceæ from Cornaceæ.

BOTANICAL SOCIETY OF AMERICA.

THE third annual meeting of this society, held in the Biological Building of the University of Toronto, on Tuesday and Wednesday, August 17 and 18, 1897, was in many ways the most successful meeting which this young but vigorous organization has had. The attendance, although not large by reason of the absence of a number of members in Europe or the far west, was representative of Canada and states from New York to Nebraska; and the papers read touched almost every great department of botany except phytogeography. An inspection of the titles given below shows that teratology, physiology, morphology, cytology, histology, taxonomy, and bibliography were all under consideration. The open sessions on Wednesday for the reading of papers were attended by a considerable number of professional botanists from England, Canada, and the United States who expressed much interest and took part in the proceedings. As foreign associate members (for this meeting only) there were present Professor H. Marshall Ward, Professor F. O. Bower, Mr. Harold Wager, Mr. J. Bretland Farmer, and Mr. J. Reynolds Green.

The business meeting of the society was held on Tuesday afternoon at 3:00, following the meeting of the council in the Queen's Hotel at 1:30. The council reported that the mail ballots received had been opened and canvassed, and announced the election of the following officers for 1898: *President*, NATHANIEL L. BRITTON; *Vice president*, JOSEPH C. ARTHUR; *Secretary*, CHARLES R. BARNES; *Treasurer*, ARTHUR HOLLICK; *Councilors*, BENJAMIN L. ROBINSON and FREDERICK V. COVILLE.

The council, after careful consideration of the invitation of the director and trustees of the Missouri Botanical Garden to hold a spring meeting of the society in St. Louis as their guests, felt constrained to recommend that the invitation be regretfully

declined at present. The semi-centennial meeting of the A. A A. S., which is to be held in Boston next year, seems to make it imperative for the society to meet there in August in further ance of its plan to cooperate with the general association as fully as possible, and the close occupation of the members o. the society renders two meetings a year impracticable. In this recommendation the society fully concurred.

Other formal invitations from Omaha, Tampa, and Old Point Comfort were read, and the secretary was directed to send suitable replies conveying the thanks of the society for the invitations.

The proposition to amend the constitution so as to reduce the entrance and annual dues from $25 and $10, respectively, to $10 and $5 met with no favor. Communications to the secretary from members who could not be present, and the adverse opinions expressed at the meeting promptly determined the fate of the amendment. It was laid upon the table.

There was also before the society the proposal to establish one or two medals to be given at intervals for valuable research. The discussion of this topic showed the sentiment of the members to be rather in favor of allowing the funds of the society to accumulate until the interest is sufficient to be used in the promotion of research by the maintenance of a table at one of the biological stations. The proposition for establishment of a medal was therefore laid upon the table.

The programme of papers for Wednesday was announced The action of the council in inviting Mr. H. J. Webber to address the society upon his recent researches upon Zamia, and Drs MacDougal and Campbell to report their observations upon Jamaica as a site for a tropical laboratory, was approved.

On the second day at an executive session the following were elected active members: Bradley Moore Davis, of the University of Chicago; Sir John William Dawson, of Montreal; James Ellis Humphrey, of Johns Hopkins University; Daniel Trembley MacDougal, of the University of Minnesota; Frederick C. Newcombe, of the University of Michigan; Henry

Hurd Rusby, of the New York College of Pharmacy; Harry Luman Russell, of the University of Wisconsin; Joseph Newton Rose, of the United States National Museum; Walter Tennyson Swingle, of the Division of Physiology and Pathology, U. S. Department of Agriculture.

The address of the retiring president was delivered on Tuesday evening by Professor Dr. Charles E. Bessey, on "The phylogeny and taxonomy of angiosperms." It is printed in full elsewhere in this number.

The following papers were read on Wednesday:

B. L. ROBINSON: *A case of ecblastesis and axial prolification in Lepidium apetalum.* 10 min. (Published in full in this number.)

J. C. ARTHUR: *Movement of protoplasm in cœnocytic hyphæ.* 45 min.

The movement was first seen by the author in 1890, and has since been studied in eight species of Mucoraceæ. It resembles, but is not quite so rapid as the movement long known in the slime molds. The movement is best seen when the fungus is growing in a very moist atmosphere. The contents of the filament, including the large and numerous vacuoles, flow in a surging stream through the principal branches, more commonly toward the growing ends of the hyphæ and the forming sporangia. But the movement is inconstant, and is often reversed, or brought to a standstill, without any regularity. The author believes that the movement is due to the osmotic absorption of water in one part and the extravasation of water in a distant part. When the filaments are turgid this change of water content displaces the whole liquid mass from the place of greater tension toward that of lesser tension, producing a more or less uniform movement. The living protoplasm is, however, credited with being the exciting and controlling agent.

JOHN M. COULTER: *Pollen grains and antipodal cells.* 30 min

Attention was called to the current views concerning the homologies of the pollen grain structures, and special objection

was made to the view which regards the pollen tube as the representative of the male prothallium. The recent discovery (in the author's laboratory) of the occasional occurrence of a small lenticular cell, cut off before the usual divisions of the microspore nucleus, and also of the occasional direct division of the "vegetative" nucleus, suggest again the older homologies. Comparison with the corresponding structures of heterosporous pteridophytes suggests that the occasional lenticular cell cut off in the germinating pollen grain represents the "prothallial" cell which constantly appears in the former, and that the pollen grain as a whole, with the exception of this occasional cell, represents the single antheridium of the heterosporous pteridophytes. According to this view the "vegetative" nucleus, with its cytoplasmic organization, represents the antheridium wall, from which the pollen tube is an outgrowth. The so-called "male cells" would thus represent the spermatozoid mother cells of the heterosporous pteridophytes.

In connection with the antipodal cells attention was called to the fact that they represent the most variable region of the embryo sac in dicotyledons, in which four types of antipodal development were noted: (1) a group of evanescent cells, usually three in number, characteristic of Amentiferæ and their allies; (2) three large antipodal cells, increasing in size with the sac, apparently very active, and usually becoming multinucleate, characteristic of Ranunculaceæ and their allies: (3) usually three comparatively permanent cells, not notable in size or activity, rather common among Sympetalæ; (4) an indefinite number of cells, forming a relatively permanent and very prominent tissue, often continuing its growth downward and breaking through the bottom of the sac, very characteristic of certain sections of the Compositæ.

FREDERIC E. CLEMENTS: *The transition region of the Caryophyllales.* 30 min. Presented by CHARLES E. BESSEY.

The history of the investigation of the transition region was discussed at considerable length. After a concise sketch of the histogenetic changes in the transition region in general, the

details of the process were given for selected genera, Dianthus, Portulaca, Allionia, Phytolacca, Polygonum, and Rumex. The author's résumé is as follows: Three types of transition may be distinguished with respect to the constitution of the bundle trace of the cotyledons; holostelar, where the trace is composed of the entire vascular system of the hypocotyledonary stele; prototracheidal, when the prototracheids are the xylem elements to pass into the cotyledons; metatracheidal, when the cotyledonary trace is formed by the metatracheids. With reference to the perfection of the transition in the hypocotyl, the transition may be truncate, or complete. In the first case, the xylem and phloem reach the cotyledons in centripetal, or secantial orientation; in the second, the orientation is centrifugal, and the stele becomes collateral.

D. P. PENHALLOW: *A revision of the species of Picea occurring in northeastern America.* 25 min.

The author reviewed the relations of the spruces of northeastern America with special reference to the possible separation of the red spruce as a distinct species. In 1887 the late Dr. George Lawson advocated the separation of the red from the black spruce with which it has been merged for the last seventy years, or since the time of Pursh. A critical study of authentic material, both in the field and in the laboratory, leads to the conclusion that the red spruce possesses well defined specific characters which separate it from all others. This evidence is derived primarily from the cones and leaves, but is supported by data derived from the internal structure of the stem. It is also highly probable that there may be another, and heretofore unrecognized variety or species of spruce closely allied to the black spruce, but further study in this direction is needed

The author also recognizes a well defined variety of the white spruce, locally known as the cat or skunk spruce, for which he proposes the name *fœtida* in allusion to its characteristic odor.

EDWARD LEE GREENE: *Bibliographic difficulties.* 30 min.

The author cited numerous instances of the complexity of

the so-called species of Linnæus, and consequent impossibility of determining to which of the segregates a given specific name ought to be applied. Thus, out of the *Viola palmata* of that author, or, at least, out of plants all answering about equally well to his brief and vague diagnosis, no less than five thoroughly distinct segregate species are recognized by botanists who know the east American violets. Meanwhile it is certain that even the synonyms by Gronovius and Plukenet, adduced by Linnæus as all three being equivalents of his *V. palmata*, themselves represent three distinct violets; and the question was raised as to whether in cases like this the Linnæan specific name ought not to be abandoned altogether, seeing that he applied it to no species, but to a group of species, and that the name befits no one of the five or six better than the others. European botanists have frequently taken such a course in dealing with such groups of species which Linnæus had mixed together under one specific name so-called. The eighteen species of North American asters named, and more or less imperfectly published by Linnæus in 1753, were discussed as being in several instances indeterminable. Scarcely one out of the eighteen is adequately described, and the greater part of those which the most critical and careful specialist finds himself able to make out, he identifies, not from Linnæus, but from those pre-Linnæan authors whom Linnæus cites as having published fuller descriptions than his own, these often accompanied by plates or figures of the species. Since many hundreds of the Linnæan plant-species are only to be identified at second-hand, by help of the references which he is constantly making to Dodonæus, Ray, Morison, Dillenius, and other earlier authors, the real identification, by Linnæan name, of a host of our species, is accomplished by a study of those authors rather than by reading the short and often nearly useless diagnoses in those little volumes of the year 1753. The paper concluded in a note of warning to those of our younger botanists, who, while accomplishing much excellent phytographic work in the discrimination of species hitherto long confused, and publishing

excellent monographs as to knowledge of the plants, are evading the bibliographical difficulties, taking little or no care to ascertain whether the form which they publish for a new one be not in reality the old type, thus taking continual risk of adding to that nomenclatorial confusion which they are endeavoring to disentangle.

WILLIAM FAWCETT: *The botanic gardens of Jamaica.*

Mr. Fawcett expected to be present, but was unable to obtain leave of absence, and forwarded the paper, with lantern illustrations, to the president, Professor J. M. Coulter. Unfortunately the paper did not reach its destination, and it was therefore read by title only. The council had invited Drs. D. T. MacDougal and D. H. Campbell to address the society in connection with this paper, giving an account of their investigation this summer of Jamaica as a site for the proposed tropical laboratory.

Professor MacDougal discussed the physical features and climate of the island, while Professor Campbell summarized the botanical features. These accounts were listened to with greatest interest, and many questions were asked, which showed the eagerness with which American botanists are looking forward to the foundation of this laboratory. All the facts will be presented later when the other commissioners visit this and other islands in the course of the coming winter.

HERBERT J. WEBBER: *Researches upon Zamia.*

By invitation of the council, Mr. Herbert J. Webber addressed the society upon his recent researches upon Zamia, which have brought to light the remarkable results, some of which have already been published in this journal, and of which a complete account will appear herein later. Mr. Webber traced the development of the megaspore and microspore, the formation of the spermatozoids, their movements and union with the egg nucleus. He also called attention to the two forms of Zamia which he has observed, and showed cones of both sorts, which he thinks are entitled to separation, varietal, or possibly specific. The existence of these gigantic spermatozoids (visible

to the naked eye!) is almost incredible until one inspects Mr. Webber's preparations, which he exhibited later to members The research not only shows many new points but opens collateral questions of great import. The exceptional interest attaching to these discoveries amply justifies the praise which Mr Webber is receiving.

ABSTRACTS OF BOTANICAL PAPERS READ AT THE DETROIT MEETING OF THE A. A. A. S.

THE following papers were presented before Section G, and in most cases the abstracts are those prepared by the author. The vice presidential address of Professor George F. Atkinson, entitled "Experimental morphology," is published in full elsewhere.

CHARLES A. DAVIS; *Trillium grandiflorum* (Michx.) Salisb.*; its variations normal and teratological.*—The variations are largely of a type common to most species of plants, in the shapes of leaves, petals, and sepals, and in the varying length of petioles. In several hundred abnormal specimens the simplest departure was marked by the presence of green stripes in the petals. This striping was accompanied by lengthening of the petioles and degeneration of the pistil. About fifty specimens were studied in which the leaves had either entirely disappeared or were reduced to bracts. In such forms the stamens are the most stable of the organs of the flower, only a few reversions to the leaf type occurring, while the pistil was usually sterile, rarely containing ovules, frequently being reduced to the leaf form, and sometimes containing well marked whorls of leaves. The petals of this form were usually nearly all green. Variations from the normal form of rootstock, and in the number of parts in each whorl of the plant to two and four, were also noted.

E. J. DURAND: *A discussion of the structural characters of the order Pezizineæ of Schroeter.*—Read by title.

K. M. WIEGAND: *The taxonomic value of fruit characters in the genus Galium.*—In certain species of Galium the fruit is saucer shaped, in other closely related species cup shaped, and in others the edge of the cup is so constructed as to leave but a pore connecting the hollow interior with the exterior.

CHARLES E. BESSEY: *Report upon the progress of the botanical survey of Nebraska.*—The survey was organized in 1892 by the Botanical Seminar of the University of Nebraska, since which time it has brought together more than 10,000 specimens; published "Reports I, II, III, and IV;" and published Parts I, II, and XXI of the *Flora of Nebraska*. The total number of species known to the state is about 3400.

ALBERT F. WOODS: *Bacteriosis of carnations.*—This disease is not due to a bacterial disease, as has been supposed, but to the punctures of aphides and thrips. The cells affected become œdemic, collapse, and give a whitish sunken spot. The dead tissue may subsequently become infested by bacteria and fungi. (Published in full in this number.)

ERWIN F. SMITH: *Wakker's hyacinth bacterium.*—Diseased bulbs were procured in 1896 from the Netherlands, and the whole subject has been re-examined. The micro-organism described by Dr. Wakker in 1883 as *Bacterium hyacinthi* is the true cause of the disease, and is quite unlike that subsequently isolated from rotting hyacinth and described by Dr. Heinz as *Bacillus hyacinthi septici*. Successful inoculations have been obtained from pure cultures, and much new information has been gathered respecting the relationships of the organism and its behavior in a variety of culture media.

CHARLES E. BESSEY: *Are the trees receding from the Nebraska plains?*—None are known to be receding, while several species, such as the bur oak and the pines are advancing.

C. A. PETERS: *Reproductive organs and embryology of Drosera.*—A detailed account of the structure and development of pollen and ovule, the former differing in some particulars from that of most dicotyledons.

J. O. SCHLOTTERBECK: *Development of some seed coats.*—The appendage to the seed of *Melampyrum pratense* is not a strophiole, nor a caruncle, nor an arillus, each of which has been claimed, but is a part of the endosperm which becomes constricted off from the rest during development. A study of the development of the seed of *Croton Tiglium* shows that its nucellus protrudes far

out of the micropyle, the only similar case known being that of *Croton flavens.*

J. H. SCHUETTE: *Contributions on wild and cultivated roses of Wisconsin and bordering states.*— Read in abstract.

FANNY E. LANGDON: *Development of the pollen of Asclepias Cornuti.*— In this study the order of cell formation has been verified by nuclear figures, thus removing all doubt with regard to successive changes. The order of development differs from the account given by Corry, the only previous writer, in the following particulars: (1) the archesporium, as in most dicotyledons, is composed of a layer of cells, and not of a single column of cells, as stated by Corry; (2) the tapetum from an early stage is composed of two to several layers, instead of a single layer; (3) Corry states that the wall of the tapetum next to the pollen becomes chitinous, and that this changed wall forms the outer wall of the pollinia, while the latter is found by the present writer to be derived in part from a secretion from the tapetum and in part from the changed outer walls of the pollen cells. The cells of the tapetum undergo remarkable changes during the development of the pollen, and probably function as glandular tissue, manufacturing a secretion which is to serve as protection to the pollen, rather than "breaking down."

CHARLES E. BESSEY: *Some characteristics of the foothill vegetation of western Nebraska.*—The foothill region is an elevated plain 1200 meters above sea level, upon which are Pine ridge on the north, 1500 meters above sea level, and Cheyenne ridge on the south, 1700 meters above sea level. Upon Cheyenne ridge occur considerable bodies of trees, mostly pines, with red cedar, box elder, and others. The Box butte plains are covered with a uniform grass formation.

H. F. OSBORN and E. B. POULTON: *Organic selection.*—Suggestions regarding the harmonizing of Darwinism and Lamarckism proposed by Professor Osborn were criticised by Professor Poulton.

JAMES B. POLLOCK: *Mechanism of root curvature.*— From experiments continued during two years it is held to be demon-

strated that the stimulus, in response to which curvature takes place, is transmitted in the cortex, either of the convex or concave side, and that the root in curving takes advantage of tensions already existing. In an unstimulated root the tissue tensions are such that every side tends to curve the root away from that side. These tendencies balance each other and the root grows straight. When the root is stimulated (as by wounding one side of the tip) an impulse is transmitted along the cortex as far as the curvature extends. The impulse produces on the side farthest from the wound a change in the protoplasm of the cortical parenchyma which makes it more permeable to water. The elasticity of the cell walls forces water out of the cells into the intercellular spaces. This shortens the cells of that side. At the same time the stimulus causes an extension, probably a growth, of the cells on the side that becomes convex. Both sides of the roots are active in producing the curvature, but their activities are of a different kind. The axial cylinder remains neutral and curvature necessarily follows.

FREDERICK C. NEWCOMBE: *Cellulose ferment.*—Account of the action of a cellulose dissolving enzyme extracted from cotyledons of seedlings of *Lupinus albus*.

RODNEY H. TRUE and C. G. HUNKEL: *The toxic action of phenols on plants.*—A study of the toxic action of phenols on living plants shows that they act less sharply and less severely than acids and heavy metals. Electrolytic dissociation plays a much less active rôle, generally speaking, than is the case in those classes of compounds, the toxic effect being due in the main to the undissociated molecules. Various radicals, when introduced into the molecule, exert a specific effect. The number of OH groups present, from one to three, does not directly affect the toxic action of phenols. The introduction of an OCH_3 group does not increase the toxic action of phenols. The introduction of one or more NO_2 groups, the substitution of a CH_3 group for an OH group, the presence of a C_3H_7 group or a COOH group, all increase in some measure the toxic action of the substance It seems certain that when plants are raised under constant con-

ditions their protoplasm with much constancy gives results which depend on the nature of the solution used, and stand in direct relation to its chemical composition.

CHARLES PORTER HART: *Is the characteristic acridity of certain species of the arum family a mechanical or a physiological property or effect?*—Preparations of the extracted juice of arum that have been filtered still preserve their acridity and produce remarkable physiological effects.

W. J. BEAL: *How plants flee from their enemies.*—It is found impossible in many cases to maintain beds of a given species for any considerable length of time in the place where they were originally set on account of various enemies from which the plants either slowly or rapidly withdraw. Water plants also exhibit peculiar habits in this respect. *Marsilia quadrifolia* has been observed to grow at different levels and in different ways, following changed external conditions.

ALEX. P. ANDERSON: *Stomata on the bud scales of Abies pectinata.*—Heretofore stomata have been thought never to occur on the bud scales of gymnosperms. They are now found on those of the species named.

ALEX. P. ANDERSON: *Comparative anatomy of the normal and diseased organs of Abies balsamea affected with Æcidium elatinum.*—Comparison shows differences in structure of leaves of the lateral and erect branches; the presence of two to six resin canals in the diseased bud scales, from which the resin, exuding through fringing hairs, spreads in a layer 1 to 3^{mm} thick over the scale; and the formation of resin vesicles in the primary cortex by the growth of the epithelial lining to the resin canals.

ALEX. P. ANDERSON: *On a new and improved self-registering balance.*

CHARLES O. TOWNSEND: *The correlation of growth under the influence of injuries.*—The purpose of the experiments conducted by the writer was to determine in what time, through what distance, and to what extent an injury inflicted upon one part of a plant will influence the growth of the injured and also of the uninjured parts. Seedlings were chiefly employed, but older

plants were used to some extent, as was also *Phycomyces nitens*. The flowering plants were injured by removing the roots as a whole or in part, or by splitting the roots near the base or near the tip; or the shoots or leaves were removed as a whole or in part. Specimens of Phycomyces were injured either by cutting away a mycelium or by removing one of the two or more sporangium stalks. In the case of the higher plants a gradual change in the rate of growth took place, and became marked in from six to twenty-four hours after injury. The influence of the irritation extended through a distance of from 0 to 300^{mm}, although this is by no means considered to be the limit through which the influence of injury is capable of acting. The change in rate of growth after injury varied from 0 to 80 per cent. of the normal rate. In the case of Phycomyces the rate of growth was reduced immediately after injury, and recovered its normal rate in from thirty to sixty minutes. In no case examined did the growth entirely cease.

W. W. ROWLEE and K. M. WIEGAND: *The botanical collection of the Cornell Arctic Expedition of 1896.*—Read by title.

ERWIN F. SMITH: *Description of* **Bacillus phaseoli,** n. sp.—*Bacillus phaseoli* is a short rod with rounded ends, yellow on various media, motile in early stages of growth, and decidedly pathogenic to beans and some related legumes, causing water-soaked spots on the pods. Its thermal death point (ten minutes exposure) is approximately 49° C., and it will not grow in the closed end of the fermentation tube with any of the common sugars. This organism is closely related to *Bacterium hyacinthi* Wakker and *Bacillus campestris* Pammel, two other motile yellow germs. It has been under observation in pure cultures for about thirteen months, and there is no doubt whatever as to its parasitic nature, all of Koch's canons for determining this point having been complied with. The three organisms here mentioned were compared and contrasted, and cultures of each exhibited, also photographs, paintings, and dried specimens.

ERWIN F. SMITH: *On the nature of certain pigments produced by fungi and bacteria, with special reference to that produced by*

Bacillus solanacearum.—The dark brown pigment produced by the potato rot bacillus will not dialyze, or does so only very imperfectly, and is precipitated by compounds of calcium and of iron. It was suggested as a working hypothesis that the humus compounds of the soil are due solely to the chemical action of fungi and bacteria on the carbohydrate materials of animals and plants, especially the latter.

ON SOME ALGAL STALACTITES OF THE YELLOWSTONE NATIONAL PARK.

JOSEPHINE E. TILDEN.

(WITH PLATE VIII)

DURING the summer of 1896, while making a collection of algæ living in the hot waters of Yellowstone Park, a curious phenomenon of algal growth was observed which, it is thought, is worthy of being recorded. It was the production by certain species of algæ of thalloid structures which, both from their appearance and their method of development, may be termed stalactites.

The most characteristic forms noticed occurred in a small cave made by the cone of a geyser. The entire inner surface of the roof was coated with the algæ, which formed shining black sheets or pendant masses of true stalactitic appearance (*fig. 1*). They looked not unlike a group of icicles depending from some ledge. Indeed, the arrangement of the grouping was quite similar, but as far as individual shape is concerned the algal thalli were much shorter, thicker, and more broadly conical than the common icicle form. Then, too, this typical shape showed variation in two directions. Many were mere knob-like processes, as large as one's fist, perhaps, while some formed masses of small, fleshy, toothed appendages. The plants chiefly concerned in the building up of these stalactites were *Schizothrix calcicola*, *Glœocapsa violacea*, and *Synechococcus aeruginosus*.

In order to explain the probable cause of this formation, it will first be necessary to call attention to a peculiar method of growth which characterizes species belonging to the group Oscillarieæ, and then to describe a little more fully the habitation of the algæ in question.

It is well known that when a bit of living Oscillatoria, Phor-

midium, or the like, is placed in a drop of water spread out on a surface, as on a mounting card, the filaments move away from each other so that they come to occupy the entire drop. In this moving about they arrange themselves in somewhat radial lines. This behavior on the part of these plants is frequently made use of in the preparation of dried mounts. A bell jar is placed over the card on which is the drop of water containing the algæ. This prevents evaporation for a few hours, which is as long as the filaments remain in action. When dried in this way the plant shows to very good advantage its texture and color.

The geyser in which the stalactites were found was situated on a knoll near the summit of a hill. Generally, the vent of a geyser occupies the center of the built-up cone. In this case the aperture was in the side of the cone, the center of which was entire and mound-shaped. This resulted in there being formed a cavity a foot or two in diameter and winding or irregular in shape. Since the opening was near the base of the cone, and small in comparison with the size of the cavity, only a limited amount of light could reach the interior. The geyser spurted hot water almost continuously, but in small quantities, which may have reached a height of a foot or two, had it not been intercepted by the dome of the deposit. As it was, the water struck the ceiling of the dome and most of it trickled back into the pit. A small stream of hot water issued from the vent with jets of steam.

The action of a geyser may undergo frequent change during its period of existence with regard either to the force exerted in projecting the water, or to the amount of water thrown off at an eruption, or to the length of the interval between eruptions. Consequently, it is reasonable to suppose that this particular geyser at some previous stage projected its stream of water to a less height than at present, that is, so that it did not come in contact with the dome. The steam, under such circumstances, would have condensed on the cold surface of the ceiling of the dome, forming drops of water which evidently would not have quickly evaporated, since they were kept in a moist atmosphere

and frequently reinforced by other condensations of steam. A place of abode of this kind, providing shade, protection, and constant moisture in small quantity, would favor the growth of such an alga as Schizothrix.

It is thought that the movement of the filaments produced in the drop of water on the mounting card is exactly what takes place in the drops of water suspended from the ceiling of the cave. These not being allowed to evaporate are soon so crowded with the rapidly growing filaments that the shape is permanently retained. Other drops are added, the alga grows into them, and a stalactite is built up. And thus, as it is not difficult to understand, the process of formation of mineral and algal stalactites is quite homologous.

In attempting to understand what must have been the past history of this algal colony, in order to account for the new form taken on by the thallus, one meets with a second problem of interest, that is, the adaptation of the algæ to their peculiar environment. Thus, (1) the algal structure is accustomed to a state of semi-darkness; even in bright sunlight the entrance of more than a small amount of diffused light into the cavity is prevented, and direct light is never possible. (2) It depends for its supply of moisture entirely upon that afforded by the eruption of the geyser. While the material that forms the cone of the geyser is of such nature that moisture can percolate through it, the fact that it is higher than the surrounding ground would leave it without opportunity for collecting moisture either in the form of rain or from underground springs. (3) It accommodates itself to the action of hot water, hot air, steam, and cold air. These forces operate at irregular but short intervals of time. (4) Accordingly, the growth is neither strictly aerophytic nor hydrophytic, but partakes of both characters.

The temperature of the hot air or steam in the upper part of the cavity was found to be 81° C., and this was probably the average temperature. Owing to the sudden bursts of steam and hot water, it was with much difficulty that a supply of the material could be secured. The greater part of this was dried

at once. Some which showed well the characteristic shape was preserved in a solution of formalin for study in the laboratory.

When first collected the algal growth showed the following features: The stratum was firm in substance; the entire surface of the sheet, teeth and stalactites was protected by a thin black membrane, fine in texture, smooth and shining; the inner parts were somewhat spongy, yet firm, and in color white, gray, or brownish, with violet, rose and blue-green tints in places. In making a cross section of a stalactite a laminated appearance was noticed (*fig. 2*). The lamellae were numerous and very thin. Some of the most perfectly formed stalactites, though not the largest, measured from 5–8^{cm} in length and 1.5–2^{cm} in diameter.

Upon returning to Minneapolis, a microscopic study of the formalin material showed that there were present a group of algae of which three members were constant. These were *Schizothrix calcicola*, *Glœocapsa violacea*, and *Synechococcus aeruginosus*, of which the following are descriptions based upon the Yellowstone material.

SCHIZOTHRIX CALCICOLA (Ag.) Gomont Monographie des Oscillariées, Ann. Sci. Nat. (Bot.) VII. **15**: 307. *pl. 8. fig. 1–3.* 1892. Tilden, Am. Alg. Cent. II, no. 180. 1896. (*Plate VIII, figs. 3, 4.*)

Stratum not encrusted with lime, somewhat gelatinous, very hard when dried, membranaceous, black or dark violet. Filaments strongly and sharply bent, interwoven; sheath firm, straight, in the beginning somewhat narrow, cylindrical, including one trichome, with age growing thicker, becoming somewhat lamellose, including two to many trichomes; trichomes pale aeruginous (after remaining in formalin several months), neither attenuate nor curved at the apex, not constricted at the dissepiments, 1.6μ in diameter; articulations in general 1–2 times longer than the diameter; apical cell rotund; dissepiments marked by protoplasmic granules.

It is the interwoven filaments of this plant alone which form the membrane of the stalactite. Empty sheaths are also present in great abundance throughout the whitish or light-colored interior.

It is necessary at this point to correct a mistake made in labeling the above species in *American Algae*, Century II. When the algae were first studied, before distributing them, although careful examination was made of various portions of the formalin material, it happened that no sheaths were found containing more than a single trichome. This made the plant appear very much like *Phormidium purpurascens*, as may be understood by referring to Gomont's description, and it was placed under this name. Later investigations have shown clearly that the Phormidium-like simple filaments are but young stages of *S. calcicola*.

SYNECHOCOCCUS AERUGINOSUS Naeg. Einz. Alg. 56. 1849.

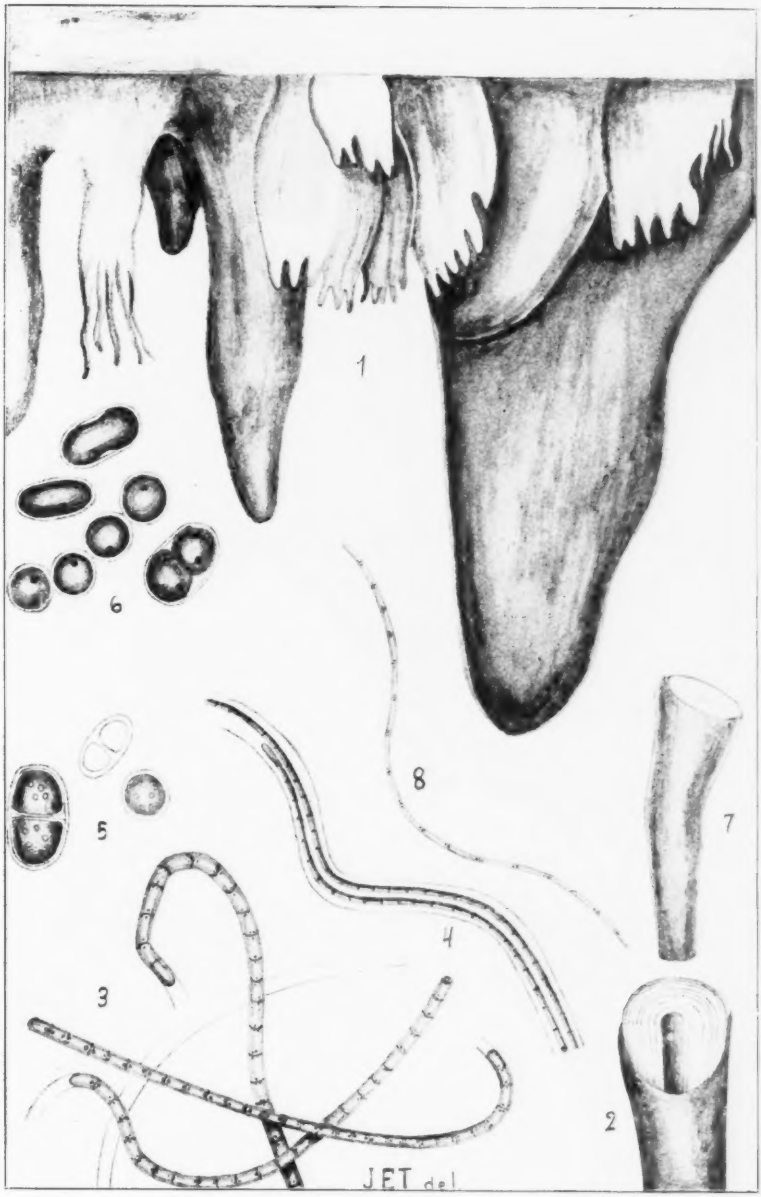
Cells 3.2–8μ in diameter, spherical or oblong, aeruginous, with thin sheath, for the most part solitary but at times four or five joined in a pseudo-filament. (*Plate VIII, fig. 6.*)

With the lower power of the microscope these cells are readily seen, as they occur for the most part in heaps or masses and are bright blue-green in color. They are found only in the interior of the thallus.

GLŒOCAPSA VIOLACEA (Corda) Rabenh. Fl. Eur. Algar. 2:41. 1865. (*Plate VIII, fig. 5.*) Forming the reddish or grayish violet portions of the interior of the thallus, mucilaginous; cells globose, 6.4–14.4μ in diameter; tegument not lamellose; cytoplasm aeruginous, granulate. These cells, for the most part empty and colorless, are very numerous throughout the interior portions of the structure.

Valley of the Nez Perces creek, Lower Geyser Basin, Yellowstone National Park. June 29, 1896.

Another species belonging to this group, *Phormidium laminosum*, is exceedingly abundant in the hot waters of the Park. In its normal condition it forms wide sheets, delicately granulose in substance, of no definite shape. It also formed hollow strings (suggesting a Tetraspora growth) rising from the bottom of hot springs and expanding at the surface into flat or bulbous masses. In a few instances it formed long narrow appendages supported by submerged grass stems (*figs. 7–8*). It is probable that



TILDEN on ALGAL STALACTITES.

these were formed in a similar manner to the stalactites already described. The stems must have first been out of the water, however, to allow the steam to condense on them. Afterwards the weight of the stalactites would draw them into the water. One of these stalactites preserved in formalin shows a length of 45^{mm}, a maximum width at the base of 12^{mm}, and a minimum width at the tip of 6^{mm}. It is abruptly truncate at the tip, and is covered with a delicate green membrane, while the inner parts are lighter or whitish in color. In most cases these pendants formed a hollow tube closed at the tip.

UNIVERSITY OF MINNESOTA.

EXPLANATION OF PLATE VIII.

Fig. 1. View of stalactites *in situ*, natural size.

Fig. 2. Cross section of a stalactite showing lamellae and hollow central portion.

Fig. 3. Young filaments of *Schizothrix calcicola*.

Fig. 4. Filament of same in later stage, with sheath containing two trichomes.

Fig. 5. Cells of *Glœocapsa violacea*.

Fig. 6. Cells of *Synechococcus aeruginosus*.

Fig. 7. Stalactite formed by *Phormidium laminosum*.

Fig. 8. Filament of *Phormidium laminosum*.

"BACTERIOSIS" OF CARNATIONS.[1]

ALBERT F. WOODS.

DURING the past two or three years the writer has had under investigation a disease of the Bermuda, or Easter lily. Early in the course of this work it was observed that the disease of the lily possessed certain characteristics in common with one affecting carnations, first described by Dr. J. C. Arthur in a paper[2] read at a meeting of this association at Toronto, August 1889. Through this paper and the publications of Dr. Arthur[3] and of Arthur and Bolley,[4] the disease has come to be generally known as "bacteriosis" of carnations. In connection with the work on the lily disease,[5] "bacteriosis" of carnations has received considerable attention during the past year, and the object of this paper is to review briefly some of the results obtained.

For a general description of the disease the following, quoted from the bulletin by Arthur and Bolley already cited, covers the ground thoroughly:

> Bacteriosis is a disease of the carnation leaf, rarely attacking the stem or other parts of the plant. It generally starts in the leaf when immature, and is best diagnosed in the younger but full-sized leaves nearest the upper end of the stem. Taking such a leaf, which on its surface presents no unusual appearance to the eye, and holding it toward strong light, small, pellucid dots may be detected scattered irregularly through the leaf, sometimes having a faint yellowish color, which are the centers of infection. The appearance of the dots has a close resemblance to those of the oil glands in the leaves of the common St. John's wort (*Hypericum perforatum*), a rather abundant weed

[1] Read at the meeting of the Amer. Ass'n Adv. Sci., Detroit, Mich., August 1897.

[2] J. C. ARTHUR, Proc. Amer. Ass'n Adv. Sci. **38**: 280. 1889.

[3] J. C. ARTHUR, Amer. Florist **6**: 419. 1891; Rep't Amer. Carnation Soc. 52. 1892; Rep't Amer. Carnation Soc. 12. 1894; Amer. Florist **9**: 467. 1894.

[4] ARTHUR and BOLLEY, Purdue Univ. Agr. Exp. Sta. Bull. no. 59. 1–38. *pl.* 8. 1896.

[5] The lily disease has been fully discussed in a bulletin soon to be issued by the Division of Vegetable Physiology and Pathology, U. S. Department of Agriculture.

or in the leaves of the false indigo (*Amorpha fruticosa*), a native shrub, except that they have no regular disposition. Sometimes the surface of the leaf is slightly raised over the dots, making watery pimples.

After a time the surface of the leaf above the dots changes enough to indicate their presence, and finally shows a distinct spot. As the disease extends inside the leaf the surface tissues collapse and whitish sunken spots appear. In some colored varieties of carnation the spots vary somewhat by being more or less reddish or purplish. As the spots increase in size the leaves wither, still clinging to the stem. Such spots never show distinct darker colored specks and rarely any concentric circles, as do the spots made by parasitic fungi, such as Septoria (spot disease) and Heterosporium (fairy ring).

Very badly diseased plants, especially when much crowded and growing in damp atmosphere, have more yellowish green leaves than normal, of a more transparent appearance, and usually smaller. The lower leaves of diseased plants in any atmosphere or soil die prematurely and the vitality of the plant is so lowered as to check the growth and decrease the size and number of the flowers.

Arthur and Bolley find that "no varieties of the carnation are exempt from the disease, but they differ much in susceptibility. The seat of this difference is chiefly in the vigor of the plant. . . . . Poorly grown plants are more affected than those well grown. Partly starved or stunted plants are specially liable to attack." They found the disease at Indianapolis, La Fayette, and many other places in Indiana, and in Buffalo, Boston, New York, Toronto, Chicago, and Lincoln. They say it is common throughout eastern North America wherever carnations are grown extensively, and conclude that it is caused by "parasitic bacteria entering the plant from the air through the stomata, or occasionally through the punctures of aphides."[6]

The disease which has formed the subject of our studies agrees in all essential points with the one just described, except that it is not caused by bacteria. Our material was obtained from many of the large centers of carnation growing in the United States, and through the kindness of Dr. Arthur good specimens were recently sent in from Mr. Fred Dorner's place at La Fayette, Ind.

[6] ARTHUR and BOLLEY, *loc. cit.* 32 and 37.

METHODS OF STUDY.

Microscopic investigations.—Material showing various stages of the disease was killed by both the chromic acid and absolute alcohol methods, dehydrated with alcohol, and infiltrated with paraffin in the usual way. Microtome sections were then cut and mounted in series, and these were stained with Ziel's carbol fuchsin, and, according to Gram's method, with anilin water gentian violet. The cells of the diseased spot were found to be much larger than normal, thin-walled, and oedemic. The chloroplasts were smaller than in healthy cells and were colorless or yellowish. Even after the most thorough and careful staining no parasitic or saprophytic organism could be detected in the tissues of these spots before the epidermal cells collapsed. In some cases after they collapsed fungi and bacteria were readily distinguished.

Cultures.—After many trials by washing and flaming it was found to be impossible to free the surface of a carnation leaf from outside germs by any means which might not also destroy germs in the tissues. Cultures were therefore made from the diseased mesophyll direct by very carefully peeling off the epidermis and scraping out the inner tissues with a flamed scraper which had been allowed to become perfectly cool. From one to twenty spots, varying in size from 0.5^{mm} to 2^{mm} in diameter, were included in each culture. Altogether about 500 cultures were made in various media, such as slightly acid, neutral, and slightly alkaline beef broth, with and without peptone; potato broth of various strengths; cauliflower broth; potato cylinders; agars of various composition; gelatin, acid, neutral, and alkaline to litmus, etc. In no case were organisms found in any culture made from a spot before the epidermal tissues had collapsed In cultures made from spots which had collapsed various fungi and bacteria were occasionally obtained, but not constantly or always of the same sort. Cultures including the epidermis frequently contained various organisms, among which was a yellow bacterium which occurred frequently on the surface of both dis-

eased and healthy leaves, and which resembled in many respects the organism described by Arthur and Bolley as *Bacterium dianthi*, the cause of "bacteriosis." Infection experiments were made with this and other organisms, but the disease was not produced in any case.

From this work and the fact that no fungi or bacteria whatever were found associated with the disease in its earlier stages we were led to look in other directions for the cause.

RELATION OF APHIDES AND THRIPS TO THE DISEASE.

Aphides.—Early in the work our attention was called to the manner in which aphides attack the plant. A careful study revealed the fact that the insects in question were seldom if ever absent from plants, and that when present in limited numbers they were capable of producing effects identical in every way with those described under the name of "bacteriosis."

Studies of serial sections of spots produced by the aphides showed a breaking or laceration of the mesophyll cells, extending from the epidermis to various depths into the leaf. Oedemic swellings start from these points, resulting eventually in the development of all the characteristic symptoms described. Colonization experiments with the aphides were repeatedly made and it was found that the insects alone were capable of producing the disease and that neither fungi nor bacteria were present until the malady was well advanced, and in such cases not regularly nor constantly. In the colonization work it was found that the insects crawl between the young leaves on the growing shoots and do most of their work where they cannot be reached by tobacco smoke in sufficient strength to kill them. It was further found that it takes about two weeks for a puncture to become visible to the naked eye, appearing first as a minute translucent dot, accompanied by slight swellings of the tissues. Severe cases of the trouble were produced in perfectly healthy plants by colonizing the insects upon them, and the new growth of badly diseased plants was kept entirely free from the malady by eliminating the aphides and other puncturing insects. These

results were obtained repeatedly in the laboratory and in the greenhouse.

Thrips.—Another form of spotting, usually accompanied by distortion of the young leaves and often of the stems, was found to be produced by thrips. These spots can be readily distinguished from the work of aphides, being very irregular in shape and having mossy outlines. The changes produced in the cells of the leaf, however, are apparently the same as those brought on by aphides, except that the mesophyll cells are not lacerated. Sections and cultures were repeatedly made from such spots produced under our control, but no organisms were obtained from the mesophyll in any case.

Throughout the work it was found that certain varieties of carnations were much more subject to the attacks of both aphides and thrips than others. Susceptibility was found to depend more upon the inherent characteristics of the individual plants than upon the variety. In most cases, however, susceptibility to attack is the direct result of improper methods of cultivation This is only expressing in another way a fact already well recognized by carnation growers, namely, that the disease under consideration is one which in most cases can be readily controlled by care in the selection and propagation of stock and attention to all the details of cultural conditions.

Summarizing it may be said that

1. The disease of carnations characterized by the symptoms already described and generally known as "bacteriosis" is wide spread and destructive.

2. In the earlier stages of the disease neither fungi nor bacteria are present, so far as can be determined by the most careful microscopic studies and bacteriological investigations.

3. As the disease advances various organisms appear, but their presence is not constant.

4. Infection experiments with such organisms, carried on under rigid bacteriological conditions, resulted negatively in every case.

5. A disease having all the characteristic symptoms of "bac-

teriosis," excepting the presence of bacteria, is produced by the puncture of aphides, as was repeatedly proved by the colonization of these insects on the plants.

6. That the aphides alone are responsible for the trouble is shown by the fact that the injuries produced are not accompanied in the earlier stages by fungi or bacteria. The aphides, therefore, can not be looked upon as carriers of any fungus or germ.

7. Injuries similar in many respects to those produced by aphides also result from the attacks of thrips, an insect nearly always present on carnations under glass, although generally overlooked by growers.

8. The carnation is a plant readily influenced by the conditions under which it is grown, and as a result the reaction to the injury of the aphides and the susceptibility to their attacks not only vary with varieties, but with individuals of the same variety. Plants, therefore, grown under improper conditions will show more of the characteristic injuries from a given number of aphis punctures than those where all the conditions have been favorable for growth.

9. Proper selection and propagation of stock; furnishing soil, moisture, light, and air best adapted to healthy and vigorous growth; and keeping down to a minimum the number of aphides and thrips will enable the grower to successfully combat the disease.

DIVISION OF VEGETABLE PHYSIOLOGY AND PATHOLOGY,
U. S. DEPARTMENT OF AGRICULTURE.

BRIEFER ARTICLES.

A METHOD OF PRESERVING THE GREEN COLOR OF PLANTS FOR EXHIBITION PURPOSES.

For many purposes, especially when intended for museums, classes in botany, pharmacy, etc., it is very desirable to preserve, as far as possible, the natural appearance of plant specimens. Where the purposes for which the material is to be used will permit its preservation in a dry state, the natural colors may generally be well preserved for some time by rapid drying. This is true of nearly all colors both of leaves and flowers. Such material, however, is likely to slowly fade, especially if it is not kept perfectly dry and well protected from strong light. Where the material is to be kept in fluid media, such as alcohol, formalin, gelatin, glycerin, etc., it is impossible in most cases to preserve the natural colors except by resorting to special methods.

The method about to be described will not preserve the colors of flowers. It is effective only in cases where some shade of green is to be preserved, that is, where the distinctive color depends on the presence of chlorophyll in all or in certain cells. Usually it will also effectively preserve the browns, reddish browns, and yellows, such as occur in injured or diseased portions of stems, leaves, or fruits.

The principle involved is to bring about a combination of the chlorophyll in the cells of the plant with copper. The resulting compound, copper phyllocyanate,[1] is practically insoluble in any of the ordinary preserving media except strong alcohol, and is not destroyed by light. If the work be properly done the resulting green can scarcely be distinguished from the normal chlorophyll green. The amount of copper phyllocyanate in each cell will be proportionate to the quantity of chlorophyll which it contained, so that contrasts and shades due to this difference will be clearly brought out.

The most difficult part of the process is to get the copper into the

[1] Tschirch, A., Das Kupfer vom Standpunkte der gerichtlichen Chemie, Toxicologie, und Hygiene, pp. 27–55. 1893.

cells before the chlorophyll escapes or breaks down. In order to accomplish this, the air on the surface, and as far as possible in the intercellular spaces of the tissues to be treated, must either be removed by immersion in 90 to 95 per cent. alcohol for fifteen or twenty minutes, according to the size and penetrative resistance of the specimen, or else be freed by placing in water and removing the air with an air pump. Soaking for some time in boiled water after the latter has cooled is also effective. Good results may be obtained by combining all these methods. When the tissues are reasonably free from air the specimens should be placed in a dilute (5 per cent.) glycerol solution containing enough dissolved copper sulphate or copper acetate to give it a marked bluish tint. The solution should be boiled before using to free it from air. At the time of using, enough formalin should be added to make the solution about 1 per cent. The specimens should be left in this until all of the green parts have been penetrated by the copper and have assumed a bluish green color. They should then be removed to a dilute glycerin-formalin solution free from copper. This will gradually dissolve all the copper not in combination with chlorophyll and thus bring out the natural shades and variations. After thorough washing and clearing in this latter solution the material may be preserved, without change, in glycerin-formalin solution or any of the common media except strong alcohol.

For class use and exhibition purposes the specimens are best mounted in glycerin gelatin. Flat specimen jars with parallel sides and clear glass may be used, or in many cases better results may be obtained by mounting the specimens between glass plates of sufficient size. Old negative plates are good for this purpose. These are made into mounting chambers by cementing narrow strips of glass between the two sides and one end, the other end being left open. The most satisfactory cement found for this purpose is Canada balsam, boiled until when cool it will be hard but not brittle. Before the cell is made the glass should be thoroughly cleaned, as it is difficult to clean the inner walls afterwards.

When the cell is prepared the material is shoved in between the plates and arranged as desired. Two per cent. formalin is then added to the warm glycerin gelatin and this is poured in at one side to the bottom, from which it rises and surrounds the specimens. Any bubbles adhering to the specimens may be disengaged with a knitting needle or a fine, stiff wire, and the material finally arranged before the

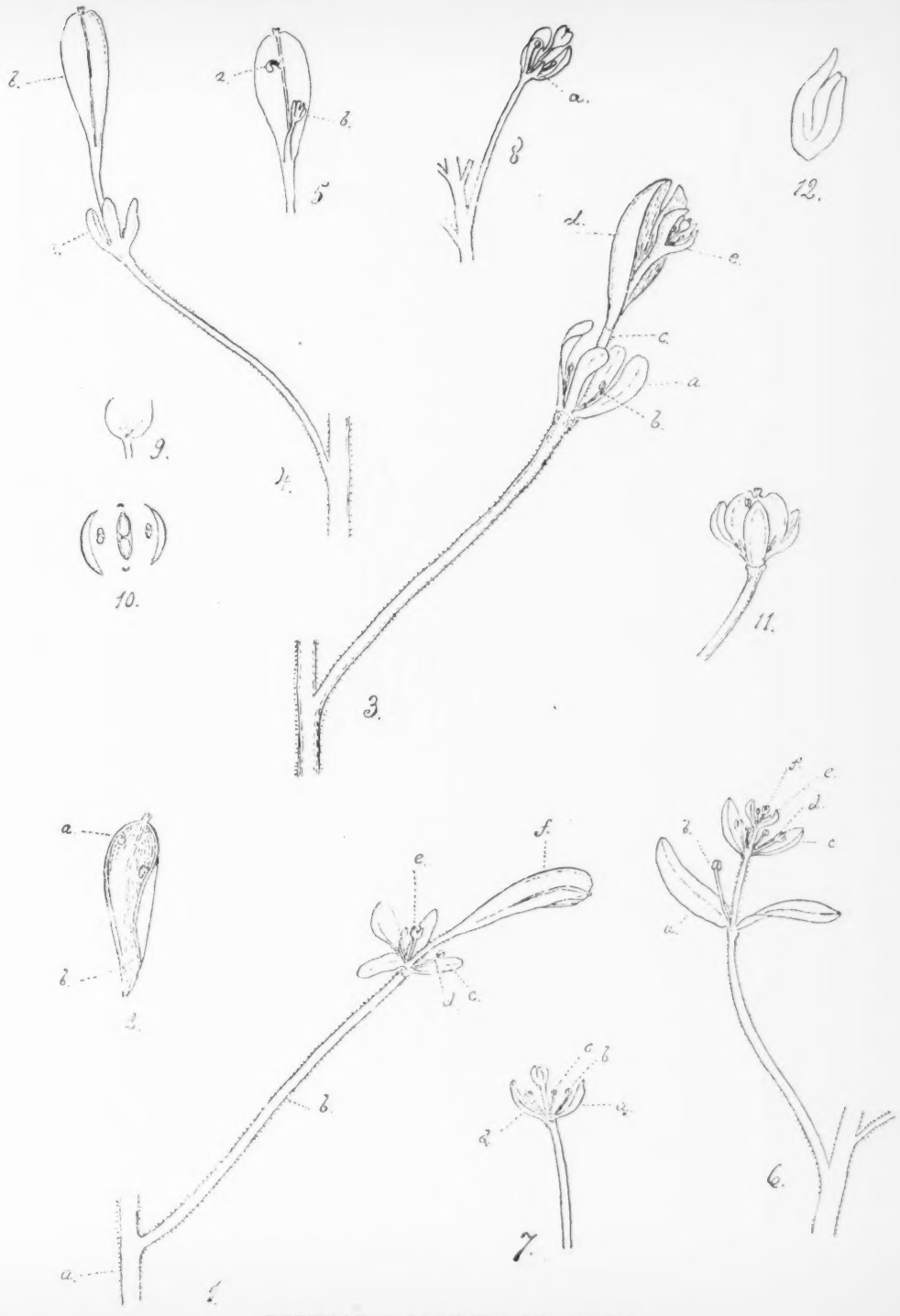
gelatin hardens. The plates should be sufficiently close so that the specimen will be held in place by friction against the glass while the gelatin is hardening. The amount of space required for different specimens is easily regulated by the thickness of the glass separating the plates. Modifications of this method can easily be made to meet the requirements of the material. The formalated gelatin hardens in a few hours, but it is best to allow the preparation to remain open at the top from twelve to twenty-four hours, filling in more gelatin if necessary. Finally, when the top has hardened and dried down about one-fourth of an inch, the space left should be carefully cleaned out and filled in with hot, hard balsam, which should make the seal perfectly air-tight. After this the mount should be cleaned, bound with lantern slide binders, and labeled.

The formula for the glycerin gelatin used is 20 parts of best quality French or other clear gelatin, 10 parts glycerin, and 100 parts water. Steam the mixture until the gelatin is melted, then cool down to 55° C., and add the white of one egg to about every 200cc. After this is thoroughly incorporated steam again for about thirty minutes, or until the egg albumen is thoroughly cooked and white. Stir occasionally during this last steaming to insure complete coagulation of the egg. Now add malic or some similar acid to make the mixture neutral or slightly acid to litmus, and after carefully incorporating this strain while hot through cloth, and then filter through paper. In case it is desired to keep any of the glycerin gelatin in stock add, before filtering, one part salicylate of soda to each 100 parts of the mixture, or else keep the stock flask sterile by occasional steaming. I use the latter method.

As before mentioned, the formalin is not added to the stock gelatin, but to what is used in making each preparation at the time of filling or imbedding. When once the gelatin is hardened by formalin it is insoluble in water and cannot be melted even at boiling temperature. The formalin, of course, also makes it antiseptic. If the formalin is permitted to evaporate from the gelatin the latter may again become fluid.

Other formulas for glycerin gelatin may be used instead of the one described.. Some prefer to use a larger quantity of glycerol and less water, which has an advantage, in that the mixture so prepared is less liable to dry out.

In conclusion the writer wishes to disclaim any originality in the



ROBINSON on LEPIDIUM APETALUM.

principles herein involved. The method is merely the application of well-known facts to economic ends.—ALBERT F. WOODS, *Division of Vegetable Physiology and Pathology, United States Department of Agriculture.*

A CASE OF ECBLASTESIS AND AXIAL PROLIFICATION IN LEPIDIUM APETALUM.

(WITH PLATE IX)

THE teratological specimen of Lepidium described below was collected by Mr. F. S. Collins at Malden, Mass., in August. Noting its remarkable character Mr. Collins has kindly referred it to the writer for examination. The plant is about 4^{dm} high, much branched, and already destitute of its lower leaves, so that it lacks some of the most characteristic features for specific identification. However, the cotyledons are distinctly incumbent, as shown in *fig. 12*, and the terminal racemes, which have normal fruit, show the orbicular pods and approximate regularly spreading pedicels characteristic of *L. apetalum* Willd., to which the plant is confidently referred. Most of the flowers show no sign of petals whatever, while in others there are rudimentary petals, as shown in *fig. 11*. These, however, have been found in normal specimens of *L. apetalum*, and therefore raise no appreciable doubt as to the identification. As mentioned above, the terminal racemes of the main axis and of several of the branches are entirely normal in their appearance. On the other hand, the numerous lateral racemes are all greatly modified. They are much looser, and the slender pedicels spread at various angles, instead of being regularly divaricate as in the normal racemes; but what is more conspicuous is the modification of the fruit from an orbicular pod to a long clavate or pear shaped body, which is not sessile in the calyx, but borne upon a filiform ascending stipe, in some cases nearly equaling the pedicels of the flowers.

The microscopic examination of one of these racemes shows a series of teratological modifications of the floral organs. Some of these changes are good examples of well recognized teratological phenomena, namely, ecblastesis and axial prolification, while others are too irregular for any very satisfactory classification or morphological interpretation. A cursory search in literature for records of similar monstrosities in the genus Lepidium has disclosed only a single mention of such

phenomena, namely, by Mr. Masters, who in his *Vegetable Teratology*, p. 148, gives Lepidium in a rather long list of genera, in which axillary prolification has been noted. However, this mention is accompanied by no details whatever, except that the prolification arose from the axils of the petals and stamens, while even the species is not stated upon which the observation had been made. The present case seems therefore worthy of record.

Unfortunately here, as in many cases of monstrosities, it is the mature plant and not its developmental stage which is known to us. Although it is possible to trace the varying malformations in the successive flowers of a given centripetal inflorescence, it is quite impossible to assume that the upper flowers represent the early stages through which the lower ones have passed, for often the modifications are very different in kind. However, in the absence of what might pass as developmental series, there is no better method open than to describe the successive flowers of a raceme, beginning at the lowest where the members are fully grown. The lowest flower in one of the teratological racemes is shown in *fig. 1*. From *a*, the axis of the raceme, the pedicel (*b*) diverges at a considerable angle and bears, at about the usual distance from the axis, the 4-membered calyx (*c*). Opposite the dorsal and ventral sepals are borne two stamens, each doubtless representing a pair of the longer stamens in the theoretical tetradynamous androecium. Of the lateral sepals one is empty, and the other bears in its axil a very rudimentary flower (*e*), which, itself scarcely larger than a stamen, is slender-pedicelled and possesses rudiments of three sepals, two stamens, and an ovary. This is, of course, a clear case of ecblastesis or budding from the axil of a floral member, for it is quite impossible to regard this little flower, with its clearly marked phyllome and caulome, as any modification of a stamen or petal.

From the center of the main flower, and quite continuous with its axis, springs what is evidently a stipitate elongated gynœcium (*f*) of somewhat irregular clavate form, bearing at the tip a small stigma, and showing upon the surfaces indication of the limits of the two carpels. *Fig. 2* represents the gynœcium with one valve removed. An ovule is borne upon each side, further demonstrating the gynœcial nature of the organ, and at the base of the capsule may be seen a very rudimentary flower, similar to the one borne in the axil of the sepal below, except that its diminutive calyx appears to have only two sepals instead of three. As this little flower is borne within and at the very base of

the gynœcium, it would seem to be a clear case of axial prolongation and prolification.

Fig. 3 represents a very similar case of prolification. Here, however, the main flower has four sepals and two stamens, without any sign of ecblastesis, while the gynœcium has undergone further development, the walls of the capsule being split down one suture, notched at the other, and thrown back as a sort of spathe-like envelope, from which emerges the here further developed axial prolification in the shape of a distinctly formed little trisepalous and diandrous flower (*e*). Its little ovary is borne upon a distinct stipe, which suggests the beginning of still further prolification. A careful examination has failed to reveal any traces of ovules or funiculi on the spathe-like organ (*d*). However, its analogy to the similar and ovuliferous structure shown in *fig. 1* is too close to leave any doubt as to its gynœcial nature. *Fig. 4* shows another flower higher in the raceme and of similar but less developed structure. The bases of two stamens were found within the calyx (*a*), and the interior of the gynœcium (*b*) is shown in *fig. 5* (where it has been divided through the middle of the valves). The placenta, which, from the way the ovary was divided, here appears as a median line, bears a single ovule, while at the base is a rudimentary flower similar to that shown in *fig. 2*.

A little higher upon the raceme occurred the proliferous flower shown in *fig. 6*. It has only two sepals, the dorsal and ventral (*a*), and one stamen (*b*) borne opposite the ventral sepal. The central axis was then prolonged and a second disepalous calyx (*c*) borne above. In the axils of each of these sepals were borne rudimentary flowers (*d*), and springing laterally from the axis at nearly the same height were three stamens. Only two of these can be shown in the figure, the third being concealed by the axis. The morphology of this flower is capable of various interpretations, and in its mature state the precise relation of the stamens to the sepals could not be satisfactorily made out; especially as the stamens were of an odd number. However, it seems likely that here the lateral sepals have been developed, and the dorso-ventral pair suppressed, while the longer pairs of stamens of the theoretical tetradynamous andrœcium are represented on one side by a single stamen, on the other by a pair. The structure of the minute flowers (*a*) was essentially as those described above, one of which is represented in *fig. 1, e*. The main axis was then produced by another distinct internode and bore another disepalous flower (*e*) which con-

tained two stamens, opposite the sepals (here doubtless the dorso-ventral pair), and in the middle a minute and obscure rudiment of still another flower (*f*). In the whole axis we have thus a case of triple prolification, together with distinct ecblastesis from each sepal of the middle pair.

The upper flowers of the raceme, which we have been following, although modified in various degrees, showed a greater and greater simplicity of structure, as will be seen from the three represented in *figs.* 7, 8, and 9. The last shows the simplest form of flower observed. Its envelope consisted of two sepals with which alternated two obscure microscopic rudiments, doubtless the inner sepals. The andrœcium was formed of two stamens opposite the developed sepals, and the gynœcium of two carpels of normal position. *Fig.* 10 shows a diagram of the flower. For the sake of comparison the normal flower from one of the terminal racemes of the same plant is shown in *fig.* 11. In this the minute rudiments of petals may be seen alternating with the sepals, and one of the two stamens is just visible protruding from behind the ventral sepal. The sessile normal capsule of orbicular contour of course presents a striking contrast to the deformed stipitate gynœcium of the modified flowers. The specimen shows an apparently sound and normal root and in general shows no cause for deformities described. The plant is preserved in the Herbarium of the Middlesex Institute at Malden, Mass.—B. L. ROBINSON, *Harvard University*.

EDITORIALS.

IT HAS SEEMED to the writer that two lines of botanical research, much cultivated at the present time, are in danger of sterility. The two lines referred to are the conventional cytology and physiology. The danger lies not in these great subjects, but in the narrow lines along which they are being cultivated. In the cytological field, by the use of various killing fluids and stains, investigators are obtaining various appearances. Aside from those well authenticated cell structures which have long been matters of common observation, these appearances are remarkably diverse, judging from the records of competent observers. Each investigator sees in his own facts a sequence of events, every step of which is necessarily an inference, no matter how reasonable it may seem to him. Enough has been observed to indicate that the maze of appearances that may be obtained from cell manipulation may not represent normal and constant phases of cell activity. It is certainly evident that the testimony obtained is ambiguous, for very numerous theories of cell operations may find support from observation, and in no field of investigation is it more true that one may find what he seeks. It is possible, therefore, that the mechanical cataloguing of these appearances may not be the most important direction of cytological investigation.

Cytology and Physiology

THERE IS NO THOUGHT to minify work that has been done, but rather to magnify the larger field that awaits cultivation. It seems reasonable to suppose that the fundamental principles of cell operations are comparatively few and simple. This would accord with all that has yet been discovered of fundamental principles. These same principles, however, may express themselves with a vast variety of detail, dependent upon conditions. Cytology is now concerning itself with this vast variety of detail, which of itself would seem to indicate that it is not fundamental, but dependent upon conditions. It would seem logical, therefore, with the details at hand, to direct investigation towards the conditions which determine these results. The

study of the effects of varying conditions upon the production of the various phases of cell activity would seem to be the fertile direction of cytology at present. Certain it is that through such investigations only will an approach be made to the fundamental principles. Such investigation has far more direct bearing upon the great problems of variation and heredity than any amount of examination of cell materials and of inference as to their relationships.

IN REFERENCE to the conventional physiology the same general statements are appropriate. Instead of attacking large problems, much of the work is advancing along purely mechanical lines in the record of isolated details. In other words, the outlying and endless details of expression of a few underlying principles are being catalogued, important enough in a way, but merely an incident in the progress of the real physiology. The fundamental problems are brought into view from the ecological standpoint. There is need of a renascence of physiology, for there has been a long period of sterility. The founders of modern plant physiology are being followed in the mechanical phases of their work rather than in their fructifying ideas.

CURRENT LITERATURE.

BOOK REVIEWS.

A new botany.

DR. WILLIAM A. SETCHELL, of the University of California, is another botanist to be added to the list of those who have attempted to meet the demand for a suitable text for secondary schools.[1] It goes without saying that Dr. Setchell's presentation of the subject is both scientific and complete, the only question being as to whether the text meets the requirements of the constituency for which it was prepared. It is true that some question might arise as to proportion of treatment when we find seven pages given to phyllotaxy and only two to the root, ten to the seed, and five to wind and insect-pollination, a fact which may perhaps be explained by the greater ease with which the favored topics may be fully treated in the school.

Turning to the main question we find in the preface (p. vii) "that this sketch is intended for beginners, either in the higher grades of the primary schools or in the secondary schools." An examination of the various chapters in the light of this statement awakens the suspicion that the author overshoots his audience, both in laboratory direction and definition. However skillfully approached by antecedent laboratory direction, the definition of a leaf (p. 25) as "an expanded, lateral structure of limited growth, borne on the stem and usually with a bud (or branch) in its axil" can stand to the average child of from twelve to fifteen years as little more than a form of words. The definition is a good working definition for the botanist, but is somewhat lacking as a working definition for the child. It is not a question of accuracy, merely one of adaptation. Concerning root hairs, we read (p. 18) "Examine the roots of the pea, bean, and corn, grown in loose, damp sawdust (or in a moist chamber), with a lens. Notice and sketch the root hairs. Upon what portions of the roots do they occur? Of what use are they to the plant?" This is the first mention made of root hairs, and indeed the only one save on p. 147, where reference is made to Kerner and Oliver for supplementary readings. No objection can be urged as to the content of the section quoted, but it is questionable whether as the result of such direction the average pupil in the "higher grades of the primary schools or in the

[1] SETCHELL, WILLIAM A.— Laboratory practice for beginners in botany. 12mo. pp. 198. New York and Chicago: The Macmillan Company. 1897. 90 cents.

secondary schools" will receive any clear cut conception of the position and function of root hairs. It is, again, merely a question of adaptation.

It is needless to multiply illustrations bearing upon the point under consideration. The book seems to be prepared for the teacher rather than the pupil. In the hands of a skillful teacher fairly versed in elementary botany it will be found of high value and exceedingly suggestive. In the hands of a teacher without previous laboratory experience its value would be greatly impaired, if not utterly destroyed. As an indication that the book was prepared for the teacher may be taken Appendix II, "Suggestions to the teacher," which covers 45 pages of the volume, the "laboratory practice" covering 129 pages. So large a proportion of space being deemed necessary for instructions to teachers furnishes at least indirect support to the view suggested above. It is a question as to whether pupils should be required to pay for suggestions to teachers, at least in such large measure.

After all, this is a criticism of a condition in our educational system rather than of Dr. Setchell's book. Conditions are so variant in the secondary schools of the country that the work possible for them, either as to content or extent, cannot yet be determined. The wide range of subjects taught, save in extremely exceptional cases, by every teacher in the secondary schools, precludes for the present, at least, the introduction of many of the methods of the specialist as well as many of his problems. The tendency is as mistaken as strong which is in the direction of the introduction of college and university methods into secondary schools. The chief objection to Dr. Setchell's book lies in the fact that it intensifies this tendency, that it fails to recognize the difference in conditions, indeed the difference in purpose which exists between secondary schools and universities.

The book will prove extremely helpful in elementary work in colleges and universities, and will find its way into the library of every teacher even though it does not entirely meet the needs of the secondary schools. Dr. Setchell is to be congratulated, not merely upon an honest attempt to solve a difficult problem, but also upon the production of a book which, both in form of presentation and content, is full of helpful suggestions.—S. C.

Cytological studies.

A notable volume[2] has recently come from the laboratory of Professor Strasburger. With certain important cytological problems to investigate, Professor Strasburger secured data from a wide range of forms by distribut-

[2] STRASBURGER (Eduard), OSTERHOUT (W. J. V.), MOTTIER (David M.), JUEL (H. O.), DEBSKI (Bronislaw), HARPER (R. A.), FAIRCHILD (D. G.), SWINGLE (Walter T.).—Cytologische Studien aus dem Bonner botanischen Institut. Separatabdruck aus den Jahrbüchern für wissen. Bot. **30**: 1–268, *pl. 18*. 1897. [Heft 2 u. 3]. Berlin: Gebrüder Borntraeger. *M* 27.50.

ing the work among seven of his research students. This method of securing large results from some single problem, rather than small results from scattered problems, commends itself to every laboratory in which a group of research students may be working. We are pleased to note that of the seven collaborators five are American students.

Osterhout investigated the spore mother cells of *Equisetum limosum*, with especial reference to the question of the existence of centrosomes and their participation in the process of spindle formation. He gives perhaps the most complete series of stages in the development of the spindle that has yet been worked out in a vascular plant. The sequence of events is briefly as follows: kinoplasmic fibers form (1) a felted layer around the nucleus; (2) they are radially placed; (3) the fibers gather in bundles; (4) the nuclear membrane disappears and the fibers come in connection with the linin network and the chromosomes; (5) the fiber bundles are arranged in two groups to form finally a bipolar spindle. Centrosomes are not found and could play no part in the process as described. The author also figures characteristic tetrad chromosomes.

Mottier has made further studies on the pollen mother cells of a number of lilies and dicotyledons, chiefly with reference to spindle development and chromosome reduction. As to the method of spindle formation, his results are in substantial agreement with those of Osterhout. He finds in lilies no such governing centers in mitosis as were described by Guignard. He shows also that the chromosomes in heterotypic division pass through essentially the same stages in the plants studied as have been described by later authors for animal nuclei, and argues strongly for the view that the numerical reduction of the chromosomes before the heterotypic division is only a pseudo-reduction, and that a qualitative division in Weismann's sense occurs in the second division. We must note that a later joint paper by Strasburger and Mottier[3] revises this conclusion, and returns to the doctrine that every mitosis is accompanied by a longitudinal splitting of the chromosomes.

The formation of small supernumerary pollen grains in the pollen tetrads of Hemerocallis was studied by Juel. He finds, as Strasburger has described, that these grains in every case owe their origin to the isolation of individual chromosomes either before or after splitting in the equatorial plate. Such single chromosomes form nuclei which function as normal nuclei in every respect. If isolated in the first division the small nucleus forms a spindle and divides, just as its normal sister nuclei. It is difficult to see how centrosomes could be present for these micro-spindles. Juel also confirms, for Hemerocallis, the method of spindle development described by Osterhout and Mottier.

Debski finds in Chara a type of spindle and cell plate formation which

[3] Über den zweiten Theilungschritt in Pollenmutterzellen. Ber. d. deutsch. Bot. Ges. Heft 6. 1897.

resembles much more closely the process in vascular plants than in the algæ to which Chara has been assumed to be more closely allied. The stages agree in general with those described by Osterhout. No functional centrosomes are to be found. "Extra nuclear nucleoles" are abundant, and seem to furnish material for the spindle fibers and cell plate. The structures assumed by Kaiser to be centrosomes are doubtless such nucleolar masses.

In contrast to the method of spindle development described for the vascular plants and Chara, Harper finds in the ascus of Erysiphe a type much more nearly resembling that described for animal cells by Hermann and Flemming. A disk shaped central body is present with each nucleus throughout nuclear division and spore formation in the ascus. At the beginning of spindle building this body is surrounded by a system of radiating kinoplasmic fibers. Then two such centers appear beside the nucleus and separate gradually to form the poles of the spindle. From these centers fibers extend and are attached to the chromosomes. In the bounding off of the ascospores by free cell formation the polar radiations of the last preceding mitosis perform an entirely new function. They grow in length and swing back around the nucleus, which has been drawn out into a beak beneath the central body, and fuse laterally to form a new plasma membrane around the young spore. The bounding layer of the young ascospore is thus composed of the same kinoplasmic substance as the polar radiations and spindle fibers. The spore wall is formed much later.

In Basidiobolus Fairchild finds very characteristic barrel shaped multipolar spindles. The fibers converge in groups, and each group ends in a strongly staining body. These bodies, taken together, make up a sort of polar plate. Here also a typical cell plate is probably formed as in Chara. Fairchild further notes the very interesting fact that in Basidiobolus we have one of the shortest possible life histories, involving at the same time an alternation of sexual and asexual fruit forms. Two successive nuclear divisions may complete the entire round of conidium and zygospore formation.

Swingle has given for Stypocaulon the most complete description of a sharply differentiated centrosome, and its division and migration during spindle development, which has yet been worked out in plant cells. The process here, also, is much the same as in animal cells. The apical cell of this plant is almost constantly in division, and the polar radiations and centrosomes persist in it through the resting stages of the nucleus. The spindle has both "mantle" and "central" fibers, and at the time of its greatest development the polar radiations are much reduced. The amount of kinoplasm at the two poles is regularly unequal. The contrast in structure and reaction of the fibrous kinoplasm and alveolar trophoplasm is nowhere more sharply shown than in this apical cell of Stypocaulon. Cell division takes place without the aid of connecting "fibers" or constriction of the plasma

mass. A cell plate is formed in the trophoplasm and is split into two new plasma membranes before the building of the new cellulose wall.

Strasburger finds that the oogonium nucleus of Fucus shows the reduced number of chromosomes in its first division after the stalk cell has been cut off. Centrosomes in the Fucus cell are sharply differentiated, and the spindle is formed much as in Stypocaulon. In cell division in the oogonium the cell-plate appears first as a layer of granules, each of which divides, and the so formed elements fuse to form the bounding membranes of the daughter cells. Fusion of the male and female pronuclei and the first division of the fertilized egg nucleus are also described. Centrosomes in connection with these pronuclei were not observed, but the presence of such a body with the antherozoid nucleus is regarded by Strasburger as not improbable. He also gives a résumé of the results presented in the different papers, and a more theoretical discussion of their bearing on doctrines of cell structure and reproduction.

While zoologists are inclining to the conclusion that the archiplasm of Bovéri is only a structurally modified portion of the common cytoplasmic mass, the evidence in all the above studies goes to show that there are two substances, kinoplasm and trophoplasm, in the cytoplasm of the plant cell, distinct both in structure and chemical composition, and readily distinguishable by their visible structure and staining properties. To the kinoplasm falls the active work of mitosis, in many cases of cell division. In the ascus it covers the entire surface of the young spore, which suggests that the *Hautschicht* may be also kinoplasmic.

We must conclude, so far as existing evidence is concerned, that there are two widely distinct types of spindle formation, the one occurring in animals and many of the lower plants, the other in the higher vascular plants. In the first the forces of mitosis act in centered systems, while in the other the kinoplasmic fibers singly or in bundles are the acting units.

The work of Mottier and Osterhout serves to emphasize greatly the similarity between the chromosome figures in animal and plant cells in the so-called heterotypic mitosis. The interpretation of these figures, however, remains still in doubt.

The whole series of studies is of great importance, and a review can do it but scant justice. The conclusions reached demand such a readjustment of former ideas that real criticism must await further investigation. Any theory, however, which differentiates the higher from the lower plants in these fundamental cell processes seems likely to have an uncertain tenure, especially as it associates the lower plants with animals. The tendency of investigation has been to establish similarity rather than diversity in all fundamental life phenomena. This objection is purely theoretical, of course, but it is so firmly intrenched in the minds of biologists that the proof to the contrary will

have to be very strong. We cannot help but feel that while the observations recorded in these "studies" are of great interest, some of the conclusions are entirely too sweeping. The occurrence of centrosomes in the higher plants is far from settled, and the occurrence of a multipolar phase as necessarily antecedent to the bipolar phase of a spindle may be regarded as still an open question.

The result of these "studies" will be to stimulate investigation greatly rather than to command immediate belief in the more important conclusions, and investigation is always more important than belief.—J. M. C.

MINOR NOTICES.

T. D. A. COCKERELL[4] has published a remarkably full list of the food plants of scale insects. The preparation of the summary has emphasized two facts, viz., "the unexpected number of coccids found on many of the cultivated trees and shrubs, and the frequency with which species dangerous to fruit trees will occur on ornamental plants, which may be carried from place to place and be the means of disseminating the scales."—J. M. C.

THE FOURTH PART of *Flora Franciscana*[5] has just appeared, and is devoted to the Compositæ. As Professor Greene has been much concerned with various sections of this great group, it is of great interest to have the results of his studies brought together, so far as they can be within the limited range of this work. Space forbids mention of the numerous shiftings of generic boundaries and the new species described. Many of the author's views of the genera of Compositæ have been published already, but the contribution before us contains much new material. The richness of the Californian flora may be judged by the fact that the portion of it represented in this *Flora* contains 113 genera of Compositæ, and 492 species. The general character of the composite flora may be judged from the following summary of the number of species under each of the ten groups called "sub-orders," and named as follows: Eupatoriaceæ 9, Asteraceæ 149, Gnaphaliaceæ 30, Ambrosiaceæ 7, Helianthaceæ 29, Madiaceæ 79, Helenioideæ 76, Anthemideæ 25, Senecionideæ 59, Cynarocephalæ 29.—J. M. C.

NOTES FOR STUDENTS.

ITEMS OF TAXONOMIC INTEREST are as follows: Karl M. Wiegand[6] has been studying *Galium trifidum* and its North American allies, and finds that this reputed "variable species" is a plexus of forms. He has used the form

[4] Proc. U. S. Nat. Mus. **19**: 725–785. 1897.

[5] GREENE, EDWARD L.—Flora Franciscana. An attempt to classify and describe the vascular plants of middle California. Part IV. Pp. 353–480. San Francisco: Payot, Upham & Co. London: William Wesley & Son. 1897. $1.00

[6] Bull. Torr. Bot. Club **24**: 389–403. 1897.

of the seed in cross-section as an important diagnostic character, and has been able to separate forms heretofore thrown together. The original *G. trifidum* L. seems to be Gray's var. *pusillum*, and other forms which have been loosely associated with it are here set apart as *G. arcuatum*, n sp., *G. tinctorium* L. with three new varieties, two new varieties of *G. trifidum*, *G. cymosum*, n. sp., and *G. palustre* L. Charles L. Pollard[7] has described two new violets, *V. Porteriana* from Pennsylvania, and *V. flavovirens* from Idaho. The same author[8] also establishes *Oxytria* Raf. as the oldest generic name for the three species commonly described under Schoenolirion. Gust. O. A.: N. Malme has recently contributed to our knowledge of South American plants by the publication of three papers based upon his own collections. The first treats of the Xyridaceæ,[9] including descriptions of four new species of Xyris and one of Abolboda. The second treats of the genus Burmannia[10] two new species being described. The third discusses the Polygalaceæ.[11]

In all of them it is important to note that the groups are presented in their biological aspects.—J. M. C.

Miss Ethel Sargant's second paper[12] on the formation of sexual nuclei in *Lilium Martagon* treats of spermatogenesis. It will be remembered that in the first paper on oogenesis the conclusion was reached that in no one of the three nuclear divisions which immediately precede the formation of the ovum is there a transverse fission of the chromosomes. Dr. Haecker's hypothesis demands that in one of these three divisions there must be a transverse fission of chromosomes, and also a transverse fission in one of the four divisions which lead to the formation of the male pronucleus.

The nuclei of the pollen mother cells pass through a period of development which corresponds in every detail to that of the macrospore nucleus. The amorphous chromatin which was described in the first paper appears again in the pollen mother cells. The synapsis stage is discussed at some length, and the conclusion is reached that synapsis is a normal phenomenon and not an artefact due to reagents. The conclusion is based mainly upon a study of living material. Three features characterize synapsis: "a more or less complete disappearance of the nuclear membrane, partial solution of the nucleolus, and contraction of the chromatin thread." In late synapsis the nuclear membrane begins to reappear, nucleoli are reconstructed from an amorphous nucleolar mass, the chromatin threads become looser, and the

[7] Op. cit. **24**: 404–405. 1897.

[8] Op. cit. **24**: 405–407. 1897.

[9] Bihang till Kongl. Svenska Vet.-Akad. Handl. **22**: [no. 2]. 1896.

[10] Op. cit. **22**: [no. 8]. 1896.

[11] Öfversigt af Kongl. Vet.-Akad. Förhandl. no. 4. 1897.

[12] The formation of the sexual nuclei in *Lilium Martagon*: II Spermatogenesis. Ann. Bot. **11**: 187–224. 1897.

familiar spirem stage is reached. The nucleus is smaller than the embryo sac nucleus of the same stage, but the ribbons have about the same width in both. "It seems probable that the linin matrix of the ribbon is formed in great part from the substance of the half dissolved nucleolus." The double row of chromatin granules is first demonstrated with certainty during the ynapsis stage, but Miss Sargant believes that it occurs earlier. As in the embryo sac nucleus, longitudinal splitting of the spirem ribbon precedes the division into the segments which constitute the chromosomes. Each of these chromosomes thus consists of two distinct longitudinal segments which separate during karyokinesis. Each of these segments shows a double row of chromatin granules, thus suggesting a fourfold character of the chromosome and recalling the tetrad of the animal spermatocyte, which in Ascaris results rom a double longitudinal fission. A second fission could not be demonstrated either in the embryo sac or pollen mother cell of Lilium. Spindle fibers appear from two or three points in the cytoplasm, forming a spindle which is rarely symmetrical at first. Attached to each chromosome are two bundles of fibers which seem to pull the chromosomes toward the poles. The daughter chromosomes in the diaster stage are commonly V-shaped.

The number of chromosomes was twelve in all cases in which they could be counted with certainty. There is a suggestion that the daughter chromosomes of the first division retain their identity within the daughter nucleus.

The nucleus of the pollen grain divides once before the grain is shed, and he daughter chromosomes separate exactly as in the vegetative nucleus. No centrosomes were observed, but there was often a differentiated mass of cytoplasm from which radiations could be traced into the surrounding cytoplasm. The generative nucleus, which divides soon after the formation of the pollen tube, shows a definite longitudinal splitting of the chromosomes. The generative nuclei are exactly alike and neither possesses a nuclear membrane or a nucleolus. In the three later divisions the number of chromosomes could not be counted with certainty, but there were about twelve.

In both spermatogenesis and oogensis the parent chromosome gives rise to daughter chromosomes by longitudinal fission. The seven divisions of these series are all distinguished by having twelve chromosomes instead of twenty-four. Of these seven divisions the first of each series differs decidedly from the rest, which are distinguished from the vegetative type only by the reduced number of chromosomes. The name "homotype," already in use by zoologists, has been given to the five divisions which follow the vegetative ype, while the term "heterotype" is applied to the first division in each series. In the spirem stage of the homotype division the ribbon stains uniformly, while in the corresponding stage of the heterotype the ribbon is bordered by a double row of cyanophilous granules. In the homotype division the chromosomes are formed of lengths of the spirem ribbon, the

longitudinal fission of the chromosomes appearing later, while in the heterotype longitudinal fission of the whole ribbon precedes the segmentation into chromosomes. Segments of homotype chromosomes appear homogeneous during karyokinesis, while those of the heterotype show a row of granules on each margin. The segments of homotype chromosomes are nearly parallel and quite regular, while those of the heterotype are twisted and contorted in the nuclear plate. Segments of the homotype diaster are usually hooked, while those of the heterotype diaster are V-shaped.—C. J. C.

NEWS.

MR. J. G. JACK will conduct a series of lectures and field meetings at the Arnold Arboretum during the autumn, for the purpose of supplying popular instruction about the trees and shrubs which grow in New England.

THERE HAS just been organized the "Louisiana Society of Naturalists." It is incorporated, and starts out with nearly forty-five members, nearly all of whom are workers in some branch of natural science. The secretary is Mr. E. Foster, of New Orleans.

MR. W. L. BRAY, who has just returned from work at the University of Berlin, has accepted a position in the University of Texas in charge of the botanical work. As his recent studies have been along ecological lines, the flora of Texas will receive his chief attention.

THE CURRENT NUMBER (September) of *Popular Science Monthly* contains an account of "The giant cactus," by Professor J. W. Toumey, and a paper upon "The scope of botany," by Professor George J. Peirce.

THE ILLUSTRIOUS Danish naturalist Japetus Steenstrup died at his home in Copenhagen on June 20, 1897, at the advanced age of 84 years. Although his most prominent works were purely zoological, he also contributed largely to the progress of botanical science. Besides being one of the editors of *Flora Danica*, he made extensive studies of the subfossil fauna and flora of the Danish peat-bogs, the result of which enabled him to demonstrate the prehistoric nature and culture in Denmark. His lectures in natural history and his warm interest for his pupils have made him one of the most popular and most admired of Danish naturalists.—THEO. HOLM.